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FINAL REPORT

LUNAR X-RAY DIFFRACTOMETER

Prepared Under

Jet Propulsion Laboratory
Contract No. 950158

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Prepared By

Philips Electronic Instruments
750 South Fulton Avenue
Mount Vernon, New York

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A B S T R A C T

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This final report documents the development of X-ray diffractometers designed to be prototypes for the Surveyor lunar landing vehicle. The developmental program was conducted by Philips Electronic Instruments under Subcontract No. 950158 to Jet Propulsion Laboratory, California Institute of Technology, under the National Aeronautics and Space Administration Prime Contract No. NAS7-100. By the technique of X-ray diffraction, these instruments were designed to analyze the mineralogical compositions of lunar materials. This information, when telemetered to the ground, will enable diffraction patterns of lunar samples to be reconstructed and analyzed on the Earth. Presented herein is the evolution of the design, development, fabrication, and test of five prototype diffractometer models.

Author

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1. INTRODUCTION

The Lunar X-Ray Diffractometer, designed to be a prototype for the Surveyor lunar landing vehicle, was developed under Subcontract No. 950158 to the Jet Propulsion Laboratory, California Institute of Technology under the National Aeronautics and Space Administration Prime Contract NAS7-100. By the technique of X-ray diffraction, this instrument was designed to provide an analysis of the mineralogical compositions of lunar materials.

This report pertains to the design, development, fabrication, and test of the following Diffractometer models:

Prototype P-3
Prototype P-3D
Thermal Model P-3
Prototype P-4
Prototype P-5

An interim final report, dated July 31, 1962, previously submitted by Philips Space Development, covered the following models: Mockup Model, Prototype A, P-1/P-2 Thermal Model, Prototype P-1, and Prototype P-2.

The Diffractometer employs a miniaturized 25kv X-ray tube of a special Philips design. Through the use of a digitally pulsed stepper motor and a precision gear train, the sample holder and detector assembly are rotated with a precise θ-2θ relationship through the desired angular range ($7°$-$90°$, 2θ) in response to commands from the Earth. The Diffractometer is designed to be used with a spacecraft sample processor which provides a powdered specimen compacted into a curved specimen holder. A divergent beam of CuK_{α} X rays, falling on the curved specimen, is focused at the receiving slit, where the diffracted beam is detected with a side-window proportional counter. The output of the proportional counter is preamplified, threshold detected, and counted down - for telemetering to the ground. Diffraction patterns of lunar samples can thus be reconstructed and analyzed on the Earth.

2. DESCRIPTION OF SYSTEM

2.1 General Description

The X-Ray Diffractometer consists of three assemblies - Diffractometer Head, Compartment B Electronics, and Power Supply. In addition, a test rack is provided for test of the Diffractometer. A block diagram of the Diffractometer is shown in Figure 2-1, and a photograph of the system, including the test rack, is shown in Figure 2-2.

The Diffractometer Head contains a goniometer for precise positioning of the X-ray detector and specimen holder, a stepper motor for driving the goniometer, an X-ray tube, a proportional counter for converting the diffracted X rays into electrical pulses, and electronics for processing of signals from the detector and amplification of command signals to the goniometer stepper motor.

Compartment B Electronics contains the logic circuitry for execution of ground commands which control the speed and direction of the goniometer drive motor and logic circuitry for generating goniometer angular position signals to be telemetered back to the ground.

The Power Supply is a DC-DC converter which supplies the necessary voltages for the Diffractometer. The high voltage (25,000vdc) can be activated on command from the ground.

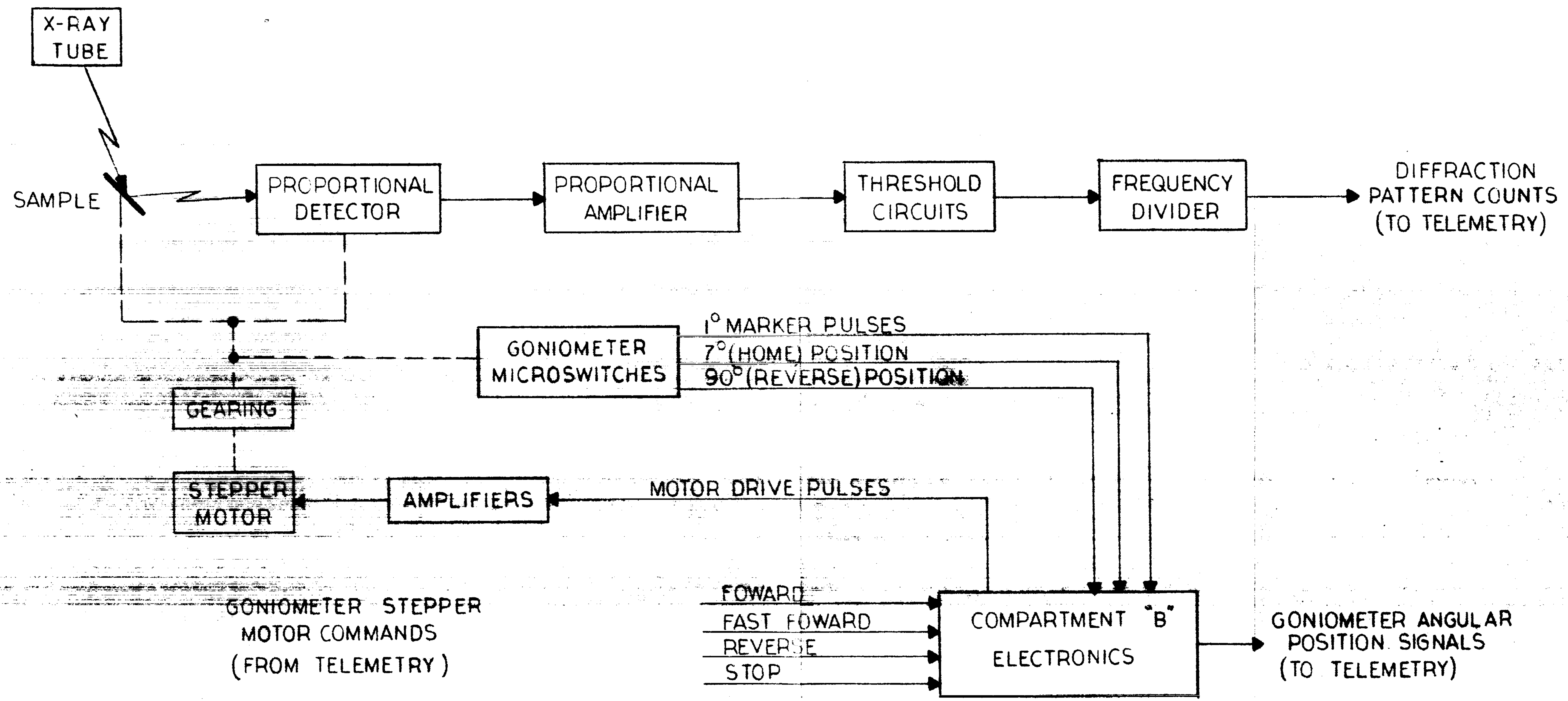


FIGURE 2-1 : X-RAY DIFFRACTOMETER BLOCK DIAGRAM

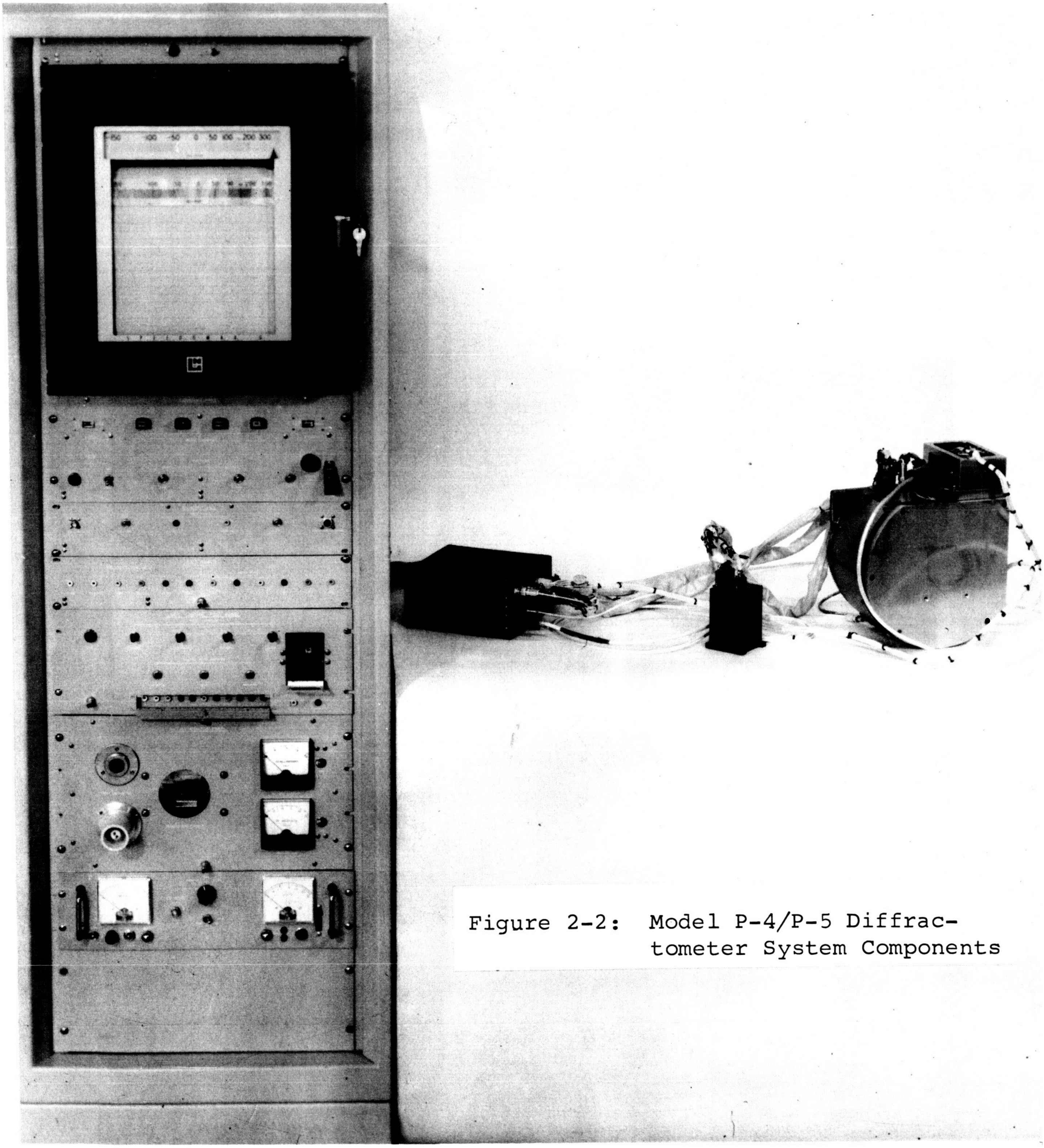


Figure 2-2: Model P-4/P-5 Diffractometer System Components

2.2 Physics

2.2.1 General

When a specimen of solid material is exposed to a beam of X rays, the various crystal planes of the material reflect the projected rays. The reflected rays form a set of concentric cones around the incident ray as axes in accordance with Bragg's Law:

$$n\lambda = 2d \sin \theta .$$

This law of crystal diffraction gives the relationship between the wavelength of incident radiation (λ), its angle of incidence (θ), and the spacing between the crystal planes (d). The patterns formed by these rays are characteristic of the specimen being examined.

An X-ray sensitive device can be used to detect the reflected radiation from the specimen. The electrical pulses from the detector are integrated and amplified and serve as a means of drawing peaks on a chart. The peaks, representing atomic inter-relationships, can be permanently recorded on a paper strip chart and provide a means by which specimens may be compared quantitatively and qualitatively. This method of analysis is extremely rapid.

The acceptablility and usefulness of the X-ray diffraction method stems from the fact that most materials are crystalline in nature. A very precise measurement of crystalline structure can be made because the X-ray wavelengths used in diffraction are of the same order as the inter-atomic spaces of crystalline matter. Many different kinds of useful information can be obtained with X-ray data, since a large part of both physical and chemical properties of matter depend on the crystalline structure of a given material.

The X-ray powder diffraction pattern obtained with any crystalline compound is unique because it is related to the fundamental crystal structure. This uniqueness makes diffraction patterns extremely useful in the identification of chemical compounds.

The X-ray powder diffraction pattern of a mixture of several crystalline compounds contains a combination of those lines characteristic of the different compounds. By refering to a suitable catalog, containing X-ray diffraction information for a wide range of materials, the constituent compounds may be identified. The number of compounds that can be identified in a diffraction pattern depends on the symmetries, concentrations, instrument resolution, computing facilities, and other factors. Most actual mineralogical samples have been successfully analyzed by the X-ray method.

These diffraction line patterns not only serve to identify the constituent compounds in the sample, but in addition, their intensity can be used to determine the concentrations of these compounds. Concentrations are generally determined by a comparison of the intensities measured in the unknown sample to the intensities obtained with known mixtures. Semi-quantitative estimates of concentrations can be made with good precision in this manner.

The minimum detectable amount of a <u>known</u> compound in a mixture is determined by the peak-to-background ratio of its most intense line. When the compounds are unknown, a sufficient number of lines must be obtained to positively identify the constituents. The minimum detectable amount of an unknown compound in a mixture is, therefore, determined by the peak-to-background ratio of the least intense line needed to identify that compound. In most cases, amounts above a few percent can be detected; in favorable cases, as little as 0.01% may be detected.

2.2.2 <u>Diffractometer Optics</u>

The Diffractometer optics has a geometrical source which is the line focus of the X-ray tube. A divergent beam of X rays from this source irradiates a relatively large specimen and the diffracted beam converges on a receiving slit. The specimen rotates at one-half the angular speed of the receiving slit. The specimen axis of rotation is coincident with the goniometer axis of rotation and is equidistant from the X-ray source and the receiving slit. In the plane normal to this "focusing" plane, the divergence is limited by two sets of parallel Soller slits.

Ideally, the line focus of the X-ray tube, the receiving slit, and the specimen surface should all lie on the same circle. With this condition,"focusing" of the diffracted radiation occurs. This enables the use of larger apertures, resulting in significant increases in the X-ray intensities recorded, an important consideration since the X-ray tube power is only 2-3% of that usually used on commercial instrumentation. Thus, for a fixed goniometer radius, the specimen curvature should be continually varied during scanning to fit the focusing circle at all θ's. Since this is difficult to accomplish, a fixed curved specimen is used. Though the correct focusing condition is then satisifed only for one 2θ angle corresponding to the particular goniometer radius and radius of specimen curvature selected, it is better than that for a flat specimen for all larger 2θ angles. For the diffractometer described herein, the 2θ angle is 30°.

Studies of effects of varying the various geometrically optical parameters: aperture angle, Soller slit dimension, receiving slit width, anti-scatter slit width, and sample curvature were described in the Final Report by Dr. W. Parrish December 19, 1960-June 30, 1961, Contract No. 950011.

2.3 Electronics

The Diffractometer Head electronics consists of two threshold circuits, a proportional amplifier, three flip-flops, and four power amplifiers.

The proportional amplifier amplifies the pulses from the proportional counter, and the threshold circuits reject those pulses which are below a preset value. To satisfy telemetry requirements, a frequency division of eight is provided by the three flip-flops. The four power amplifiers, one for each winding of the stepper motor, amplify the motor drive signals received from Compartment B Electronics.

The Compartment B Electronics consists of six major circuits - memory, clock mixer, clock scaler, reversible scale of four, marker generator, and motor step generator.

The four goniometer drive motor commands, telemetered from the ground, are stored and executed by Compartment B. This is done by logically converting a clock frequency to a sequence of pulses, appearing on four separate lines, at a rate and sequence in accordance with the commands. Compartment B also receives three commands from the goniometer microswitches and puts out signals for telemetering back to the ground. Two of these signals indicate when the goniometer is in the 7° (home) position and the 90° (reverse) position. The third command is a series of 1° goniometer marker pulses.

All command input lines contain circuitry which require that the command pulses be greater than a preselected minimum. These "no trigger" circuits were added to Models P-4 and P-5 to prevent noise pulses from activating the command circuits.

The Power Supply, a DC-DC converter, generates five voltages: 25,000vdc, 5-7 volts p-p, 6vdc, 28vdc, and 2000vdc. The 25,000vdc for the X-ray tube is turned on by command telemetered from the ground.

3. EQUIPMENT DESCRIPTION

3.1 Diffractometer Head

3.1.1 Electrical

The head electronics consists of a proportional counter, proportional amplifier, threshold circuits, binary scaler, and four power amplifiers - one for each winding of the motor.

The output of the proportional counter is applied to a voltage amplifier with a gain of 60db and a bandwidth of 4mc. It is a four-transistor configuration, utilizing complementary symmetry in a DC loop with an emitter follower output. The output of the amplifier is applied to a threshold (amplitude discriminating) circuit which drives a series of three flip-flops. The output of these flip-flops, which divide the counts by a factor of eight, is sent to the telemetry system.

The threshold circuits (reversed biased diodes) prevent pulses lower than a specific level from passing to the output. The actual level of discrimination is chosen by command from one of two preadjusted values. There is also a peak level circuit, preadjusted, which prevents pulses greater than the preset value from passing to the output. Thus, the threshold circuits form a "window" and allow only those pulses whose amplitudes fall within this "window" to pass to the scaler. This peak level circuit was added to Models P-4 and P-5.

The "no trigger" circuits (see Figure 3-1) were incorporated in the ground command input lines to make the command circuitry insensitive to noise pulses. The circuit consists of a back-biased diode and a Zener diode whose total effect is to require the command pulse to be greater than 4 volts. The back-biased diode determines the minimum acceptable command pulse voltage, and the Zener diode prevents the back-bias voltage from turning on the input transistor of a command input circuit.

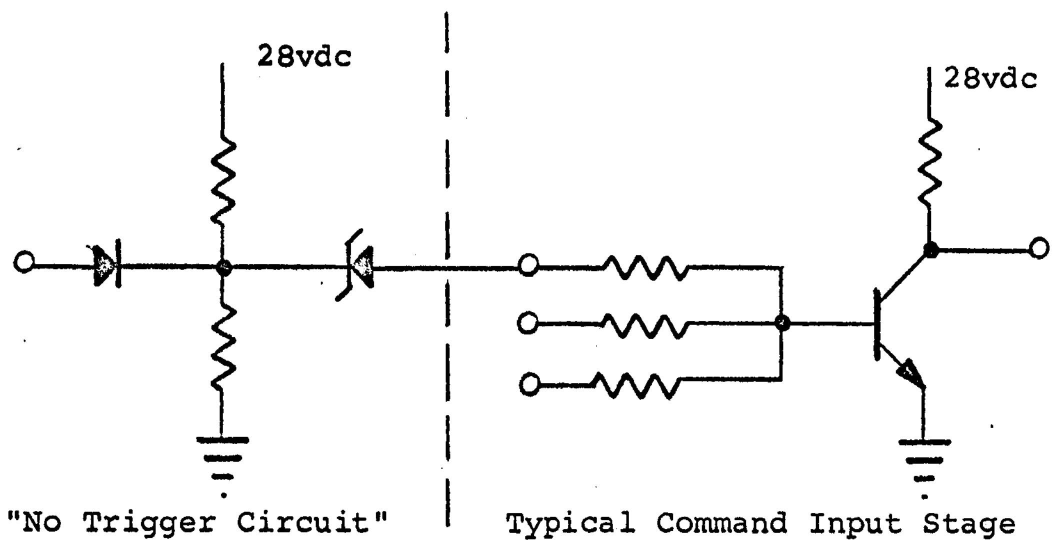


Figure 3-1: Schematic of "No Trigger" Circuit

3.1.2 Mechanical

3.1.2.1 General

The design of Prototype P-3 Diffractometer Head is based upon the designs of the earlier models - Prototypes A, P-1, and P-2. Similarily, Prototypes P-4 and P-5 are design extensions of Models P-3 and P-3D. Model P-3D was built concurrently with and is identical to P-3 and was used for developmental testing. This discussion describes the design changes from Models A, P-1, and P-2 to Models P-3, P-4, and P-5.

3.1.2.2 Prototype P-3 Diffractometer Head

The performance and mechanical design of Prototypes A, P-1, and P-2 were analyzed, and areas of redesign were then outlined. The basic goniometer geometry was considered acceptable, and the test data was within the requirements of JPL Design Specification No. 30846. Mechanical redesign and electrical packaging was then initiated to improve the following elements of the instrument:

1) outer dust cover
2) goniometer casting
3) goniometer gear train
4) counter tube mounting
5) counter tube connector
6) upper collimator assembly and adjustments
7) sample holder shaft and adjustments
8) lower collimator assembly
9) angle marker cam
10) home and 90° cam and switch arrangement
11) motor mount

12) thermal plate
13) X-ray tube connector
14) packaging of motor drive and associated input/output circuitry
15) sample eject system
16) connectors and wiring

The following is a description of the mechanical design of Model P-3 Diffractometer Head.

1) Outer Dust Cover. The outer dust cover is the main structural member of the instrument. The design of this cover was based upon considerations of:

- structural integrity
- spacecraft interface
- installation, removal, and servicing of internal assemblies
- size and weight
- fabrication techniques
- thermal considerations

The dust cover can be considered as two main assembly members: the cover casting (see Figure 3-2) and the rear support cover (see Figure 3-3). The cover casting has a sample eject cover in addition to miscellaneous sheet metal cover plates. The cover casting was designed and contoured to enclose the goniometer. It is a semi-cylindrical enclosure with installation of the internal assemblies accomplished through an opening on one end. The casting has a number of openings, serving to both reduce weight and provide access ports. These openings are covered by removable thin sheet metal plates.

Figure 3-2: Diffractometer Head Outer Dust Cover Casting

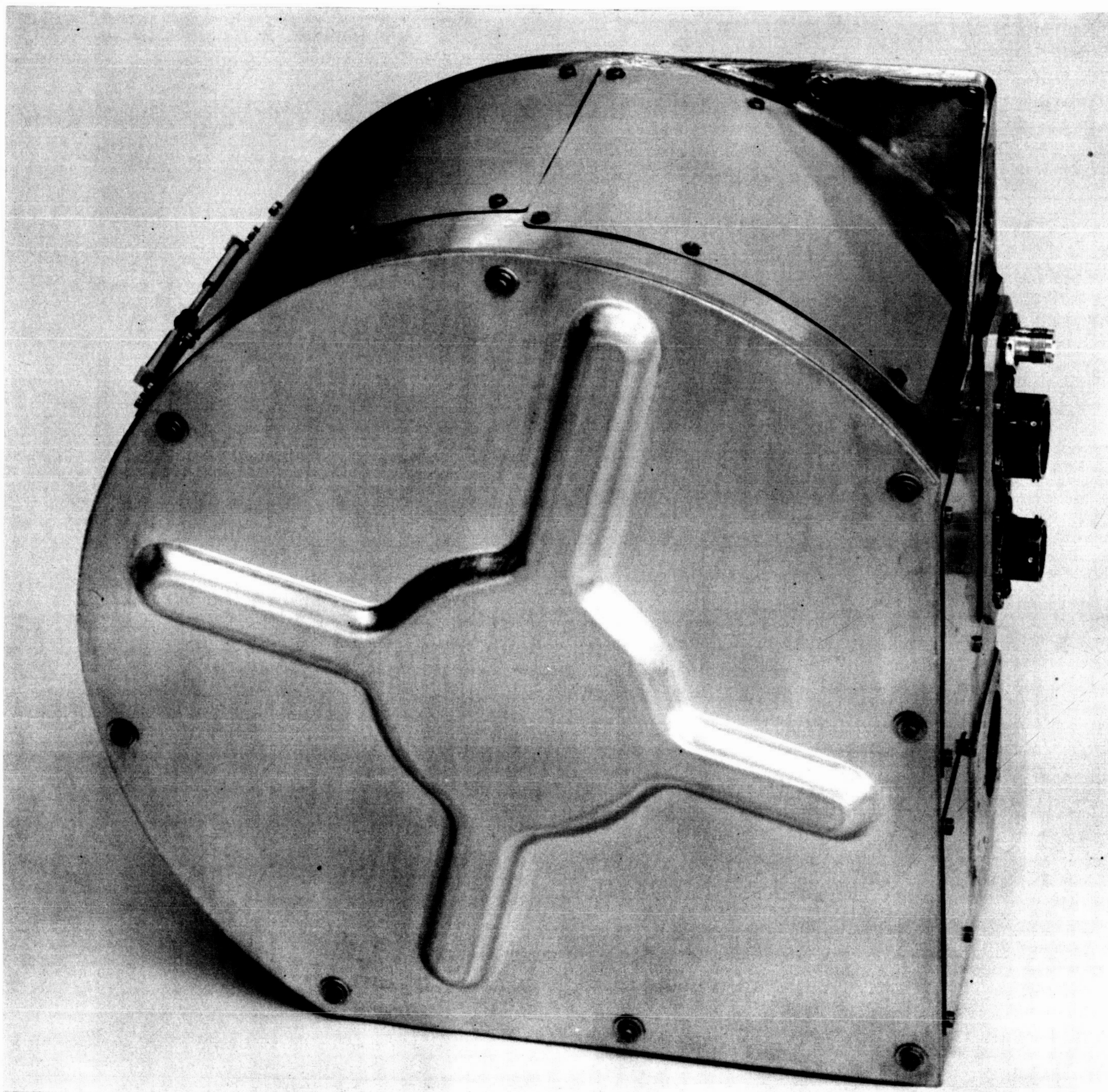


Figure 3-3: Model P-3 Diffractometer Head (Showing Rear Support Cover

The rear support cover also provides structural support. The original design used a thin sheet metal cover that was diagonally dimpled to decrease the transverse deflection ("oil canning") characteristic. This design survived vibration testing, however, a post-test inspection revealed elongation of the clearance screw holes in the rear cover. This hole distortion was due to the induced relative motion between the screws and rear cover - the rear cover moving radially with respect to the cover casting. This problem was eliminated by adding a 1/8" aluminum ring to the inside surface of the rear cover to provide additional stiffness.

Pertaining to the spacecraft interface, the cover casting was designed in accordance with the outline and mounting drawings of HAC Interface Specification No. 239284. Four tapped holes are located on the sample insertion side for securing the head to the spacecraft. Two additional tapped holes with pilot bosses are centered on the sample insertion slit centerline to mate, support, and align the HAC sample transport system.

The cover casting is a sand casting made of 356-T7 aluminum. There are cored holes around the outer circumference to minimize the structure weight. Complete sets of X rays were taken of each casting to assure that there were no internal defects. A sand casting of so large a member with thin (nominal 3/32") cross-sectioned walls required an extensive pattern making-pouring study. The results of this study produced castings that survived head environmental testing per JPL Specification No. 31144.

A thermal analysis of the Diffractometer Head suggested finishes for the outer dust cover (and thermal plate) as shown in the following table (see Figure 3-4 for surface references):

Table 3-1: Outer Dust Cover Surface Finishes

Surface	Material	Surface Finish	Thermal Finish
A1	Al.356-T7	Buffed	HAC White Paint
A2	Al.356-T7	Buffed	HAC White Paint
A3	Al.356-T7	Buffed	HAC White Paint
A4*	Al.2024	Clear Anodized	HAC White Paint
A5	Al.356-T7	Buffed	Polished Al.
Interior of Dust Cover	Al.356-T7	As Cast	HAC Black Paint or Black Anodize

*Refers to Thermal Plate, remainder of wall Al.356-T7.

2) Goniometer Casting. The goniometer aluminum sand casting was redesigned to provide each shaft with end bearing support (see Figure 3-5). The structure is essentially "U" shaped with the reverted gear train within the vertical walls. Structural members or surfaces were provided to mount the home, 90° and 1° angle mark switches, and the motor drive circuitry.

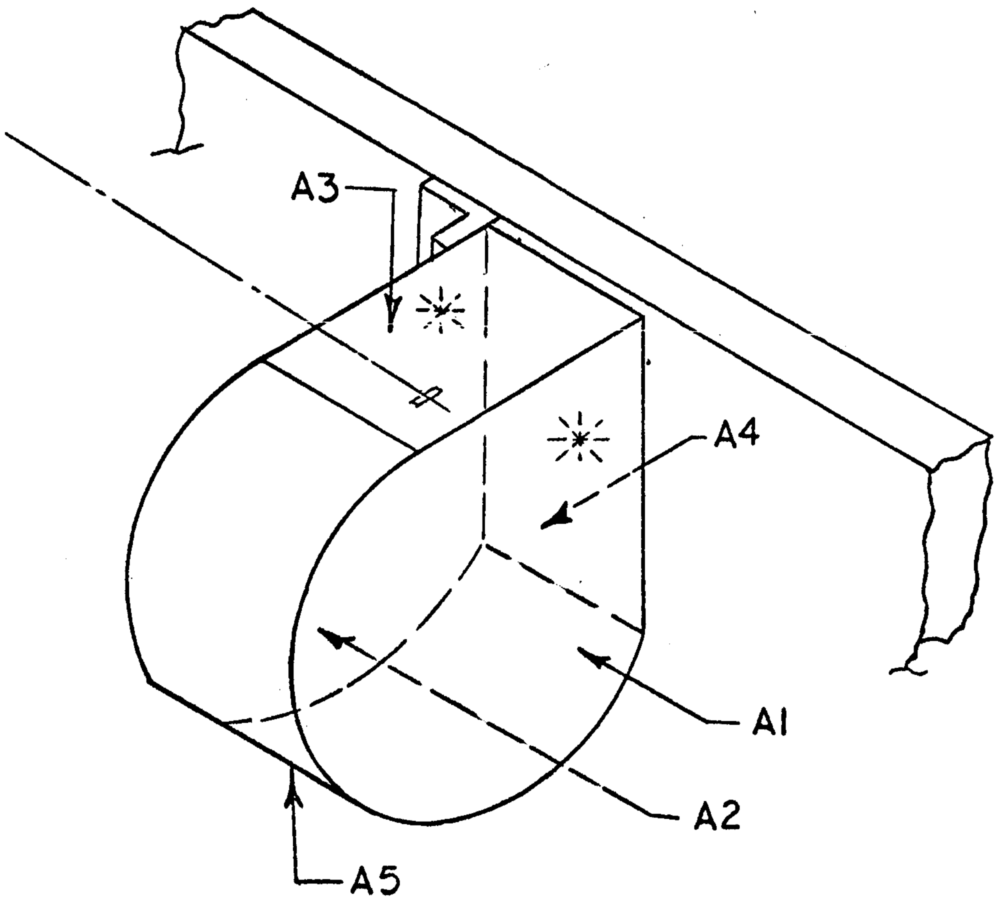


Figure 3-4: Model P-3 Outer Dust Cover Surface References

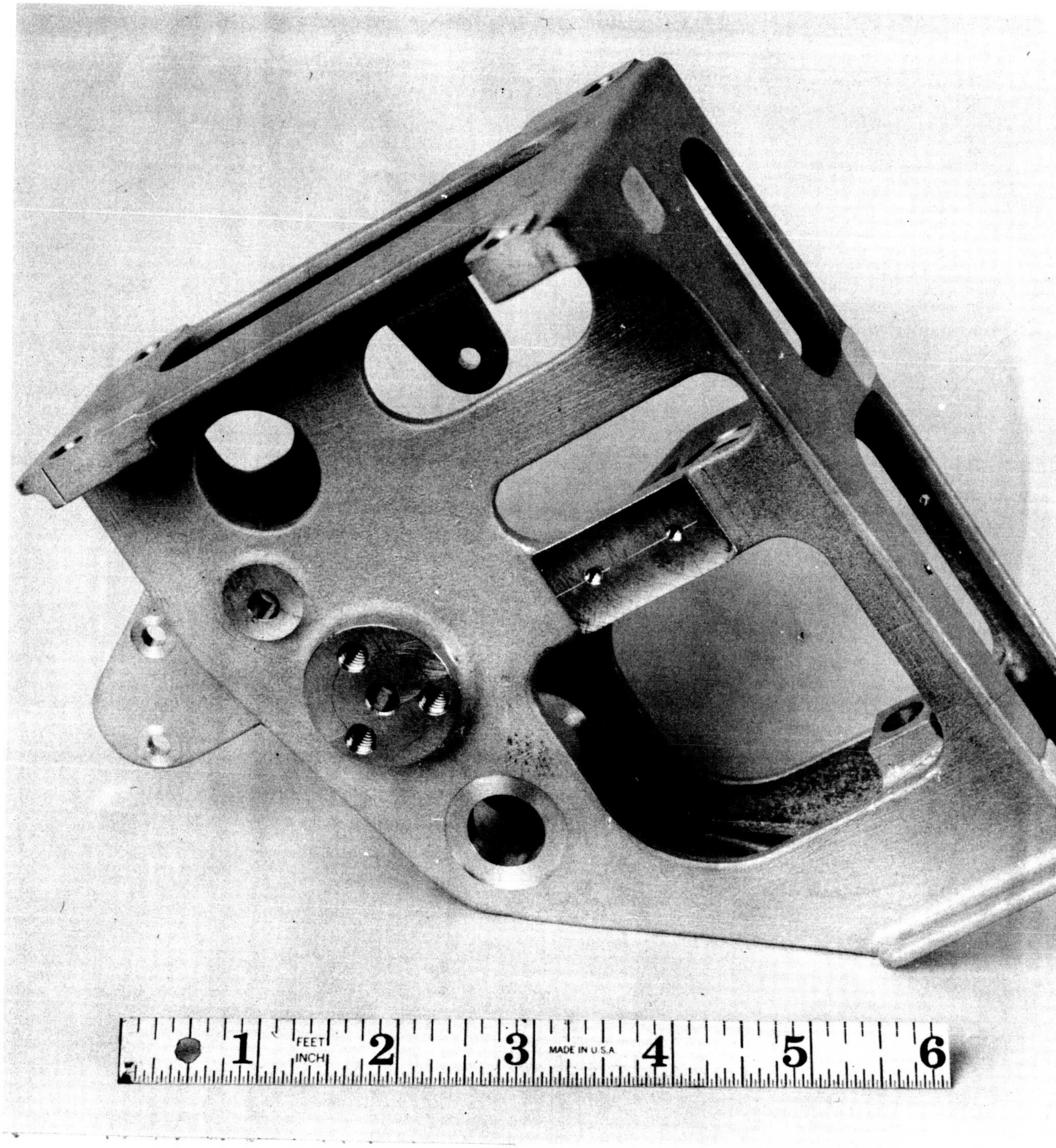


Figure 3-5: Goniometer Casting

3) Goniometer Gear Train. The goniometer gear train was redesigned to provide support for the upper collimator and mounting arm of the proportional counter tube. The weight contributed by each gear was considered and reduced where possible.

4) Counter Tube Mounting. Models A, P-1, and P-2 used end-window point proportional counter tubes as detectors, while Model P-3 uses a side-window proportional counter, Amperex No. DX241. This change required a redesign of the detector tube support. The support consists of a two-piece clamp, one-half of which is attached to a worm wheel gear and is integral to a support arm. The second half is a separate part. When secured to the support arm, the tube is cantilevered with the window over the upper collimator facing the specimen.

5) Counter Tube Connector. Electrical connection to the counter tube is made through a cross-shaped threaded contact which mates with the counter tube end cap thread. The connector is floated (not directly secured) to the tube to allow for eccentricities between end cap and tube outer diameter and prevents stressing the ceramic to metal seal when clamping. The contact is mounted in an oversized "T" slot of a boron nitride insulator. This machined shape provides the floating action and still retains mechanical security. The insulator is inserted into a circular beryllium copper cylinder of the same diameter as the counter tube. The

connector is clamped to the support arm in a manner similar to that of the counter tube. A separate ground clamp is secured to the tube to assure a positive electrical connection.

6) <u>Upper Collimator Assembly</u>. This assembly consists of collimator foils, an anti-scatter slit, and a receiving slit. It is bearing mounted to the support arm, directly below the counter tube. The bearing mount permits the collimator to be rotated for optimum alignment. The two slits are mounted in concentric cylinders and can be individually adjusted for proper alignment with the X-ray axis. The mountings are designed to permit individual slit removal.

7) <u>Sample Holder Shaft</u>. The sample holder shaft is supported by bearing surfaces within a hollow worm wheel shaft. The opposite end of the shaft from the holder is placed between a bifurcated clamp with two radial adjusting set screws placed diagonally opposite each other. A leaf spring permits working one screw against a holding force, after which the second screw is advanced to capture the precise holder position.

8) <u>Lower Collimator Assembly</u>. The lower collimator assembly is mounted to the goniometer casting, between the X-ray tube and sample holder. Three slotted radial holes permit the collimator to be rotated into position. The collimator housing has a groove into which the divergence slit assembly is placed and secured. This slit assembly arrangement is similar to that of the upper collimator assembly.

9) Angle Marker Cam. The angle marker cam was redesigned to reflect minimum force to the stepper motor. For this application, a one-piece square-shaped cam was designed. The corners of the square are rounded into the caming surfaces to successively actuate and release the angle marker switch. The reflected force was further reduced by making the switch actuator arm long relative to the cam diagonal. With this design, the motor stall torque was not approached.

10) Home and 90° Cams and Switch Arrangement. The home and 90° cams are ramp-type pieces that fit over gears in the goniometer assembly. Two screws, through a slotted groove, permit adjustment of the cam to actuate the switch at the proper angle.

11) Motor Mount. The motor-gear head assembly was cantilevered and synchro-mounted to the goniometer casting. Because vibration tests revealed excessive movement of the motor, a cylindrical housing with a base flange was installed for added stiffness. Additional vibration tests proved this assembly to be acceptable.

12) Thermal Plate. The X-ray tube anode, which is the major heat generating element in the Head Assembly, is mounted on the thermal plate. The goniometer assembly is also mounted to this plate. This complete assembly is installed, as a unit, into the outer dust cover. An opening in the dust cover permits access to the electrical terminals on the X-ray tube.

13) X-Ray Tube Connector. The X-ray tube is connected to the power supply through a Philips designed plug/receptacle connector. This special connector was made of boron nitride to withstand high voltage, temperature, and vacuum conditions. The receptacle has a cylindrical section that fits down over the tube, and a flange that mounts to the top of the outer dust cover. Male pins are soldered onto the tube filament pins and piloted into holes in the receptacle. The plug is the termination end of three power supply high voltage leads, one-25kv lead, and two filament. It has two internal female contacts which mate with the male pins of the X-ray tube receptacle. One high voltage lead and one filament lead are soldered together at one of the female pins. A "Z" bracket clamps the two halves together and secures the assembly to the outer dust cover.

14) Packaging of Motor Drive and Associated Circuitry. The motor drive circuitry is contained on a printed circuit card that is mounted to the goniometer casting, directly beneath the motor. The motor leads are soldered to terminals on a terminal board which is separate from the card. This enables removal of the motor without disturbing the printed circuit board.

The output circuitry is designed on a flat printed circuit board, while the proportional amplifier is a cordwood module mounted on the board assembly. This composite assembly is a plug-in unit that is guided into the head assembly on machined rails. The board's receptacle is fixed to the rail terminations. A cover plate on the outer dust cover permits access to the board.

15) Sample Eject System. After analysis a sample is removed from the specimen tray holder arm by insertion of the next sample. The holder is approximately twice as long as the specimen tray and is designed so that the next inserted tray pushes the tray of the specimen just examined off the holder.

To allow the sample to fall free of the outer dust cover, an explosive bolt is actuated which holds down a spring-loaded sheet metal cover located beneath the sample holder. The displaced specimen tray will then fall through this uncovered opening in the dust cover.

The actuator was made by Unidynamics, a division of Universal Match Corporation, and is their prototype Model No. 31-000-6341. The design characteristics are as follows:

a) The ignition system will withstand a 100ma no-fire current for at least one minute.

b) Ignition will be effected by a 2ms, 580ma pulse.

c) The bolt will withstand axial loads up to approximately 45 pounds.

d) Upon receipt of the firing pulse, the bolt will function within 15ms and move a flat plate weighing 14 grams a minimum of 8 feet vertically.

e) There will be no fragmentation upon actuation.

f) The weight of the actuator system is 8 grams.

g) The ignition system and explosive components are contained in a welded, hermetically sealed unit.

h) A shear pin is provided which, upon actuator firing, is designed to fail and allow the plunger, #6-32 screw and hatch cover, to eject.

16) Connectors and Wiring. The cable harness assemblies were designed to permit their fabrication external to the instrument. The cable connector flanges are mounted to a split plate which mounts directly to the dust cover casting.

3.1.2.3 Prototype Models P-4 and P-5 Diffractometer Heads

The P-4 and P-5 Diffractometer Heads (see Figures 3-6 and 3-7) retained most of the design features of the P-3 Head, except for the following changes:

1) encapsulation of the X-ray tube
2) redesigned rear cover plate
3) addition of "no trigger" circuitry
4) change in connector type

1) Encapsulation of X-Ray Tubes. In the P-3 instrument, corona and high voltage arc-over were encountered near the X-ray tube connector. The immediate solution to this problem was to eliminate any ionization paths between the X-ray tube pins and points of lower electrical potential.

The first sealing method used the same connector as designed for the P-3 instrument with the addition of a rubber gasket ring placed over the ceramic portion of the tube and seated on the shoulder where the ceramic changes diameter. The boron nitride connector section was then piloted onto the ceramic tube section. A hold-down clamp would then apply positive pressure against the elastic member and entrap the air contained within the body of the connector. This assembly operated considerably better than the tube without a gasket but was still not considered as the final solution to the problem. .

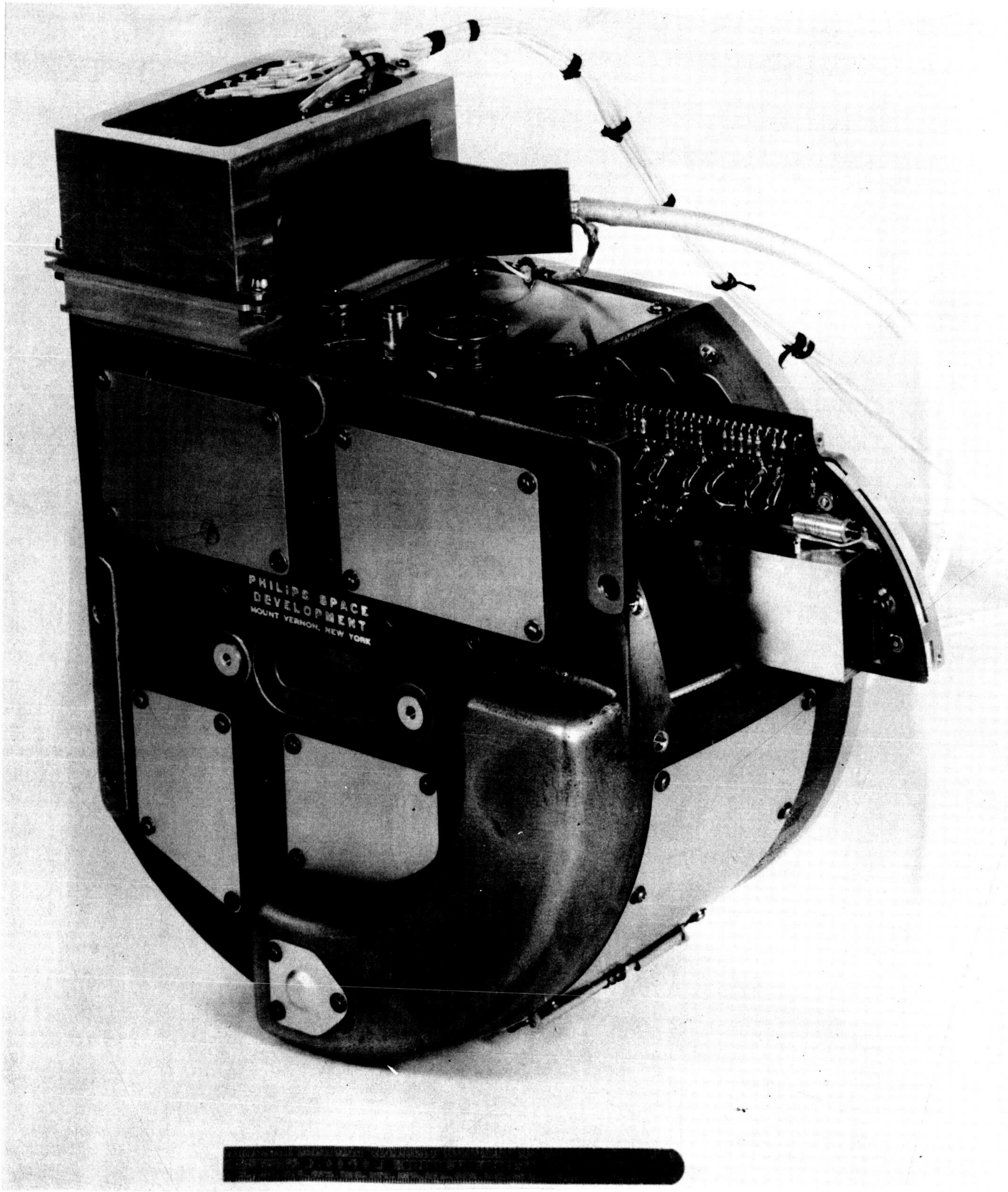


Figure 3-6: Model P-4/P-5 Diffractometer (Front View Showing Electronic Board Extended)

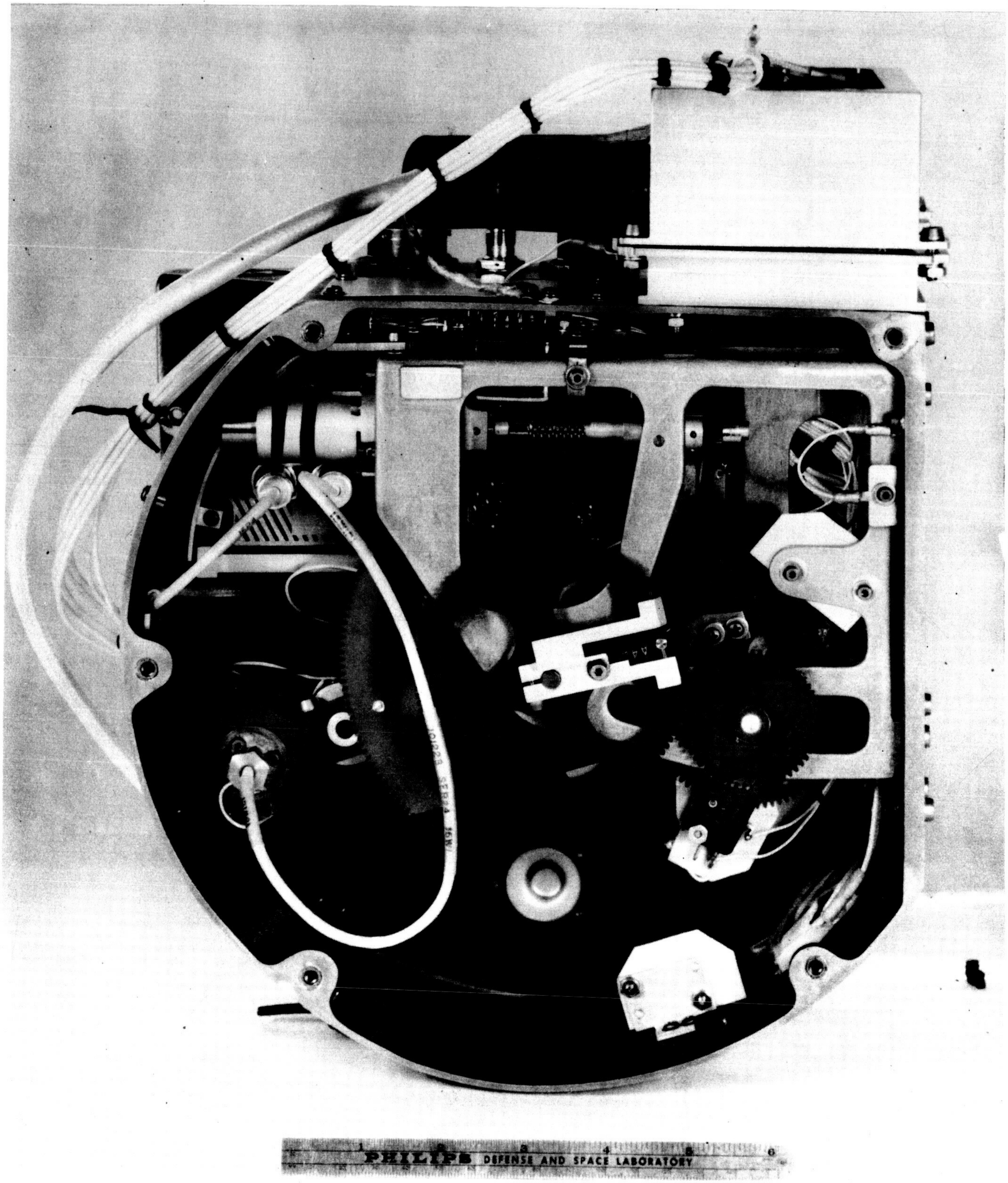


Figure 3-7: Model P-4/P-5 Diffractometer Head (Rear Plate Removed)

The next method considered was complete encapsulation of the X-ray tube in an epoxy compound. This design was suggested to JPL via PEI ECP-8 dated August 13, 1963, and an authorization to proceed was subsequently initiated.

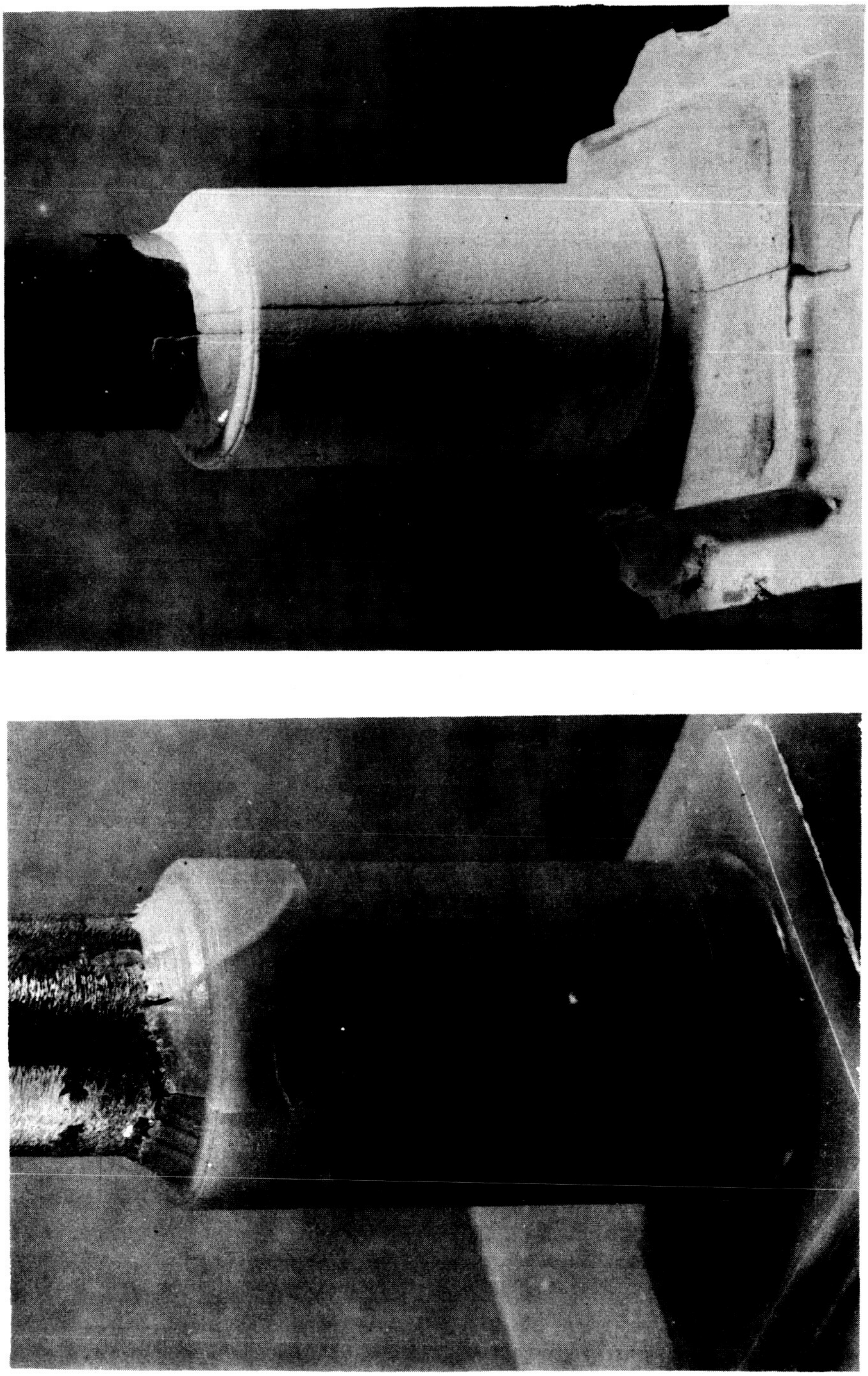
The P-3 instrument has three high voltage wires from the power supply to the head, i.e. two filament, one -25kv. The main purpose of the encapsulated design was to enclose all high voltage points succeptable to arc-over. Since the multiplier block and filament transformer are also at high voltage, it was apparent that these elements should also be sealed. Examination of the wiring and packaging led to the conclusion that the filament transformer should be located in the same encapsulated block as the X-ray tube. As a result, there is only a single interconnecting high voltage wire, and its terminations at either end are completely enclosed. The low voltage leads are brought out through terminals on the top of the X-ray tube block, to which wires from the power supply cable are soldered.

An extensive program was then undertaken to find or develop an encapsulant material of the proper dielectric, thermal, and mechanical characteristics. Compounds were specially prepared of materials made by Scotchcast, Conap, Hypol, Biggs, CIBA, and Sytcast.

Initial tests of dielectric versus temperature, ability to pour, machining characteristics, and hardness were made on standard test specimens. These tests resulted in the elimination of most of the compounds. Of the remaining group, two Hysol compounds exhibited superior overall performance.

A thermal developmental test was performed with these two potting materials. This non-operating test consisted of vacuum casting a rejected X-ray tube and a filament transformer, in a form approximating the final configuration, and subjecting this module to a +300°F to -300°F temperature test. There was no discernible effect at the high temperatures. This result was anticipated since the epoxy materials are cured at high temperatures. The modules were then subjected to a cold thermal shock by placing them immediately into a cold chest at approximately -150°F and then lowering the temperature to -300°F. The results of this test are shown in Figure 3-8. Note the cracking at the epoxy to metal interface. This was attributed to differences in thermal expansion characteristics and epoxy tensile strength. However, it should be noted that both these castings were "high-pot" tested to approximately 35kv with no electrical breakdown.

A program was then organized with the Hysol research chemist to prepare a specific compound that would be compatible with the X-ray tube material over the temperature range. The results of this investigation lead to a formula using Hysol XF019 and 4186 with approximately 0.3% by weight of glass fiber filler #2845. This last ingredient was added to increase the tensile characteristic under temperature extremes. A test specimen was then cast with this new compound. This unit survived the cold temperature test,and two good X-ray tube modules were cast. To expedite system delivery, it was agreed with JPL not to thermally retest these two deliverable units.



(b)

(a)

Figure 3-8: Encapsulated X-Ray Tube - Thermal Test Models

Concurrent with this investigation, a design phase was started to repackage the X-ray tube into the head assembly. In Model P-3, the X-ray tube and goniometer are mounted to the thermal plate as a subassembly. This subassembly is placed, as a unit, into the outer dust cover. For the new design, this was now no longer possible since the X-ray tube module was larger (encapsulated) and the high voltage line was an integral part of the tube (no connector).

For the P-4 design, the X-ray tube is inserted into a preassembled head consisting of goniometer, thermal plate, and outer dust cover. The existing tube connector hole in the outer dust cover was enlarged and shaped to allow the tube anode to pass through the cover. The tube is then secured to the thermal plate.

The final configuration of the encapsulated X-ray tube and filament transformer is shown in Figure 3-9. A box-like two-piece clamp was designed to secure the module to the casting. The bottom section of the clamp is screwed to a machined surface of the casting, and the top half is bolted to the bottom half. This assembly was not vibration or shock tested, as per agreement with JPL.

2) <u>Redesigned Rear Cover Plate</u>. The rear cover for Model P-3 consists of a support ring and sheet metal cover, as described in Paragraph 3.1.2.2 - 1). To avoid the two-piece construction and improve structural characteristics, a single

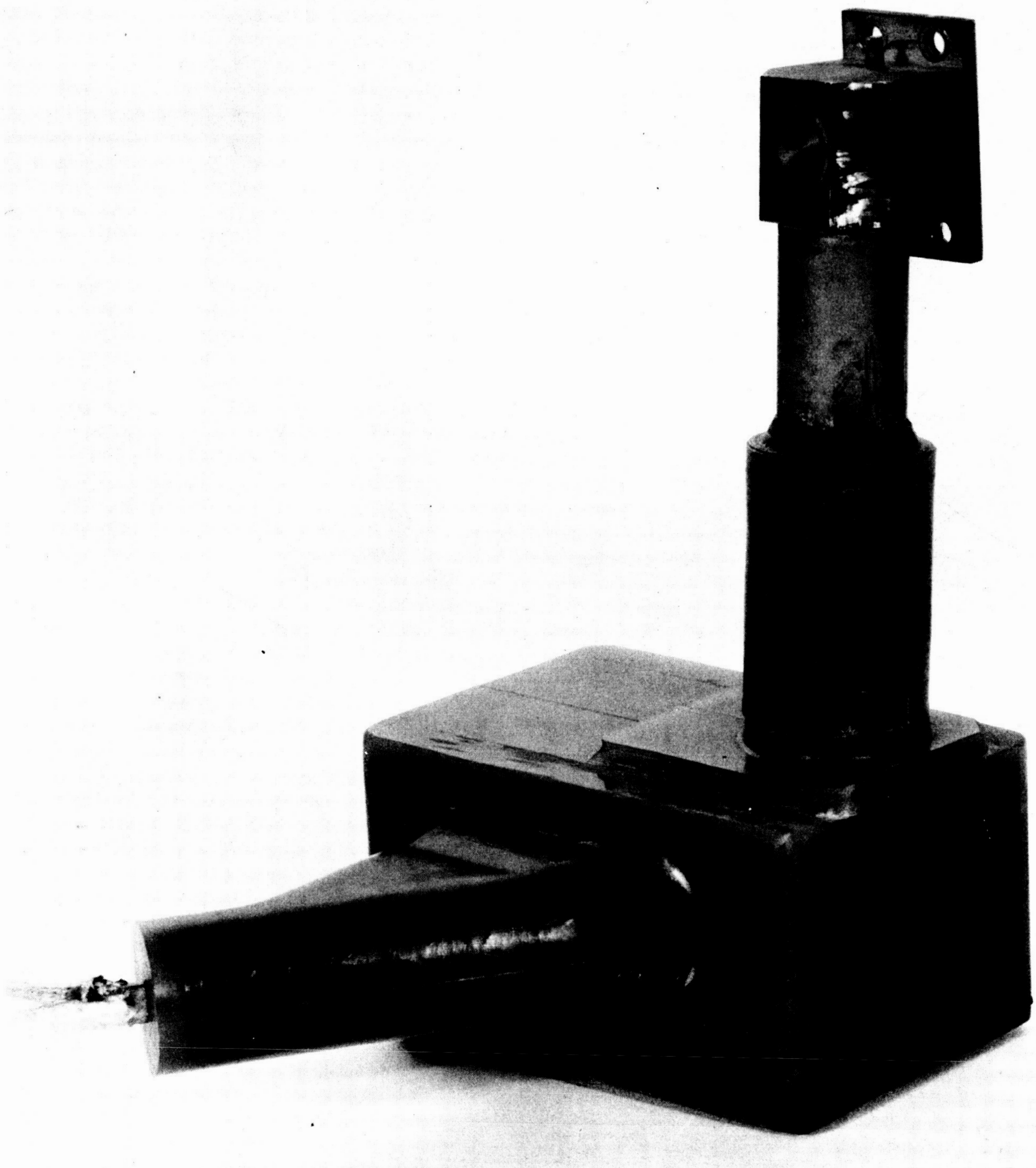


Figure 3-9: Model P-4/P-5 Encapsulated X-Ray Tube

rear cover was made of 2024 aluminum plate (see Figure 3-10). This part was machined to a thin wall with internal ribs and suitable mounting holes. In addition, two additional spacecraft instrument mounting holes were placed into bosses on the cover, as per a HAC/JPL/PEI spacecraft interface meeting held on May 8 & 9, 1963. This provision allowed for the addition of a spacecraft bracket for improved instrument support. Figure 3-10 is a view of the Head showing this rear plate.

3) "No Trigger" Circuitry. As per JPL ECR No. PEI-2 dated March 11, 1963, additional circuitry was added to the Head electronics board to prevent noise pulses from triggering the command input circuits. A larger board was designed to mount the added circuitry. In order for the Head to accomodate this increase in size, the board had to be reoriented with respect to the side wall of the dust cover casting. As a result, the design of the board guide rail was modified.

4) Change in Connector Type. In Model P-3, the use of a split plate and oversized holes in the casting wall permitted the cable harnesses to be preassembled external to the equipment. The flange of the connectors was mounted to the split plate which in turn was mounted directly to the casting.

In order to eliminate the split plate and its associated hardware, "D" mounting-type connectors are used. The cable harness connectors can then be mounted directly to the casting wall and held in place by jam nuts.

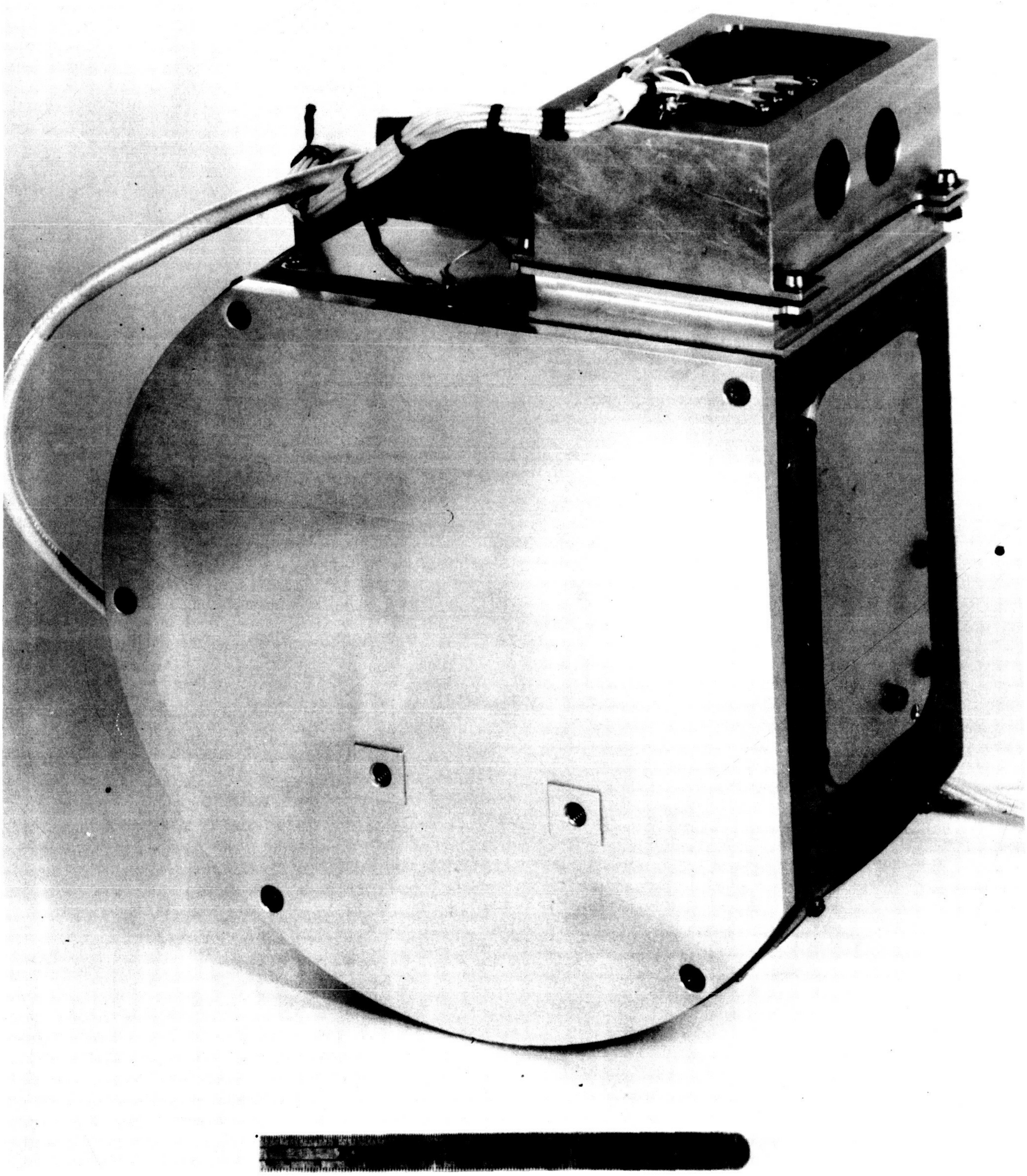


Figure 3-10: Model P-4/P-5 Diffractometer Head (Rear View)

3.2 Compartment B Electronics

3.2.1 Electrical

The goniometer stepper motor commands, telemetered from the ground station, are sent to the motor command memory. This circuit (see Figure 3-11) is a tetrastable device which, upon receipt of a command, cancels the previous and stores the new command. The outputs from the motor command memory are sent to the clock mixer. This circuit consists of three NOR circuits,which accept the motor commands, followed by a NOR/inverter combination, which provides a single wire output. Depending upon which command has been given, two of the three NOR circuits are disabled by the motor command memory. The third NOR, being enabled, allows a particular clock frequency to be passed through to the NOR/inverter.

This clock frequency controls the rate at which the goniometer drive motor rotates. In the normal scan mode (Forward), the frequency is 5.6cps which corresponds to a goniometer scan of 0.5° per minute. In the Fast Forward mode, the frequency is 45cps which corresponds to a goniometer scan of 4.0° per minute. In the Reverse mode, the frequency is 90cps which corresponds to a scan of 8° per minute. These frequencies are obtained by binary frequency division of an astable multivibrator, oscillating at 90cps.

The output of the clock mixer is applied to the "reversible scale of four" circuit which consists of two complementary binary stages and two NOR/inverter combinations. Depending upon the direction of scan commanded, the second binary is

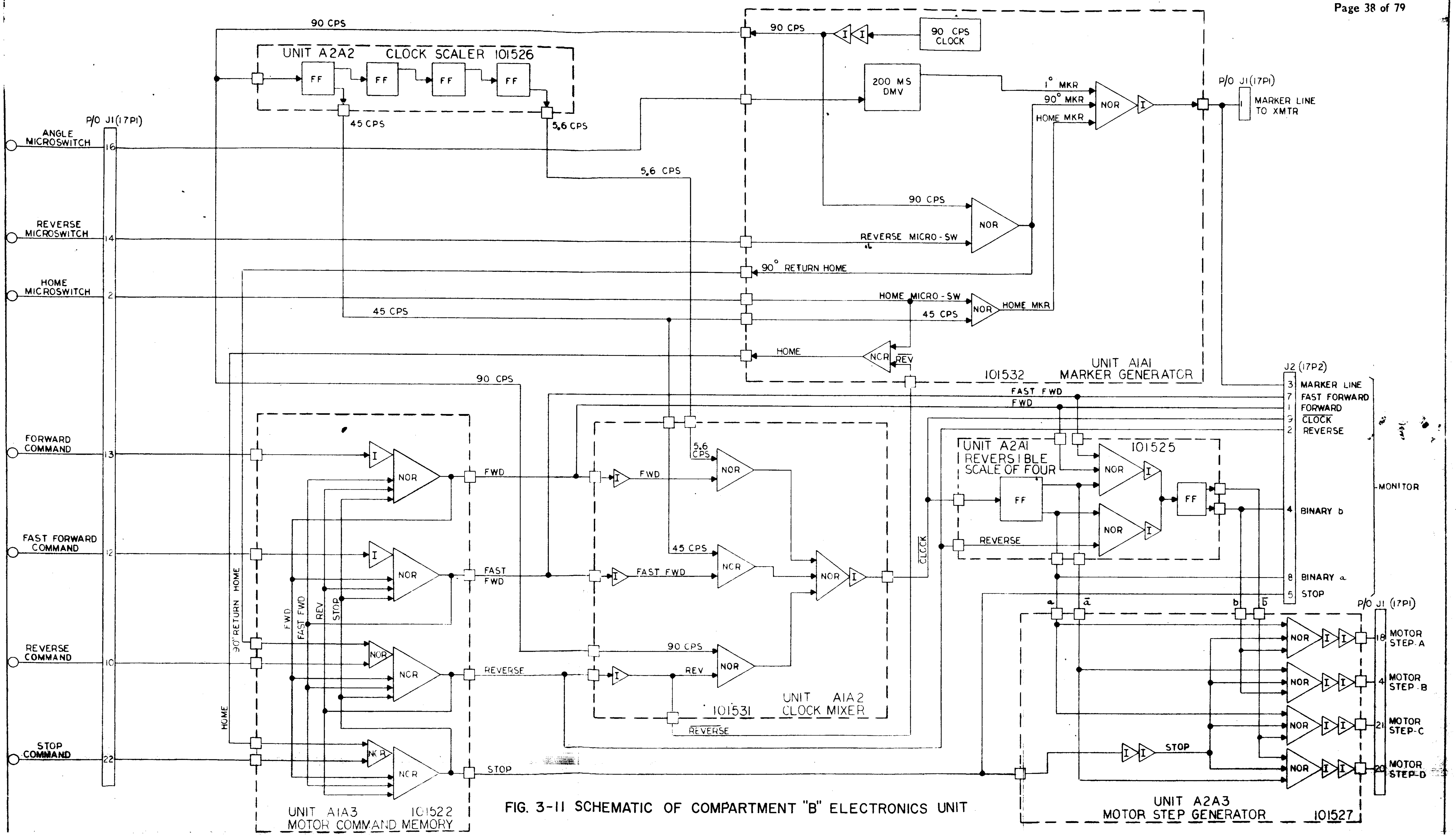


FIG. 3-11 SCHEMATIC OF COMPARTMENT "B" ELECTRONICS UNIT

triggered from either the "1" or "0" side of the first flip-flop. This "steering" is accomplished by the use of the NOR circuits which are enabled and disabled by the state of the motor command memory. The four collectors of the binary stages are applied to the motor step generator.

The motor step generator consists of a group of four NOR/double inverter combinations. The flip-flop collector wave-forms from the "reversible scale of four" circuit are matrixed in these NOR circuits, resulting in the appearance of a series of sine-sequenced pulses at the four outputs of the motor step generator. These outputs are applied to the power amplifiers, in the Diffractometer Head, which drive the gon-iometer digital stepper motor.

3.2.2 Mechanical

There were few changes incorporated in Compartment B (see Figure 3-12) from the earlier Models A, P-1, P-2 and Models P-3, P-4, P-5. The main differences were in the layout of the two distribution boards, in the mechanical design of the housing, and the addition of "no trigger" circuitry.

1) Distribution Board Layout. The two distribution boards provide the electrical interconnections between the six cord-wood modules and the two electrical connectors that comprise the package. In the redesign, the wires from the two con-nectors were brought to separate terminals on the distribu-tion boards. This permitted the wiring harnesses to be fab-ricated external to the unit and allowed the wires to be

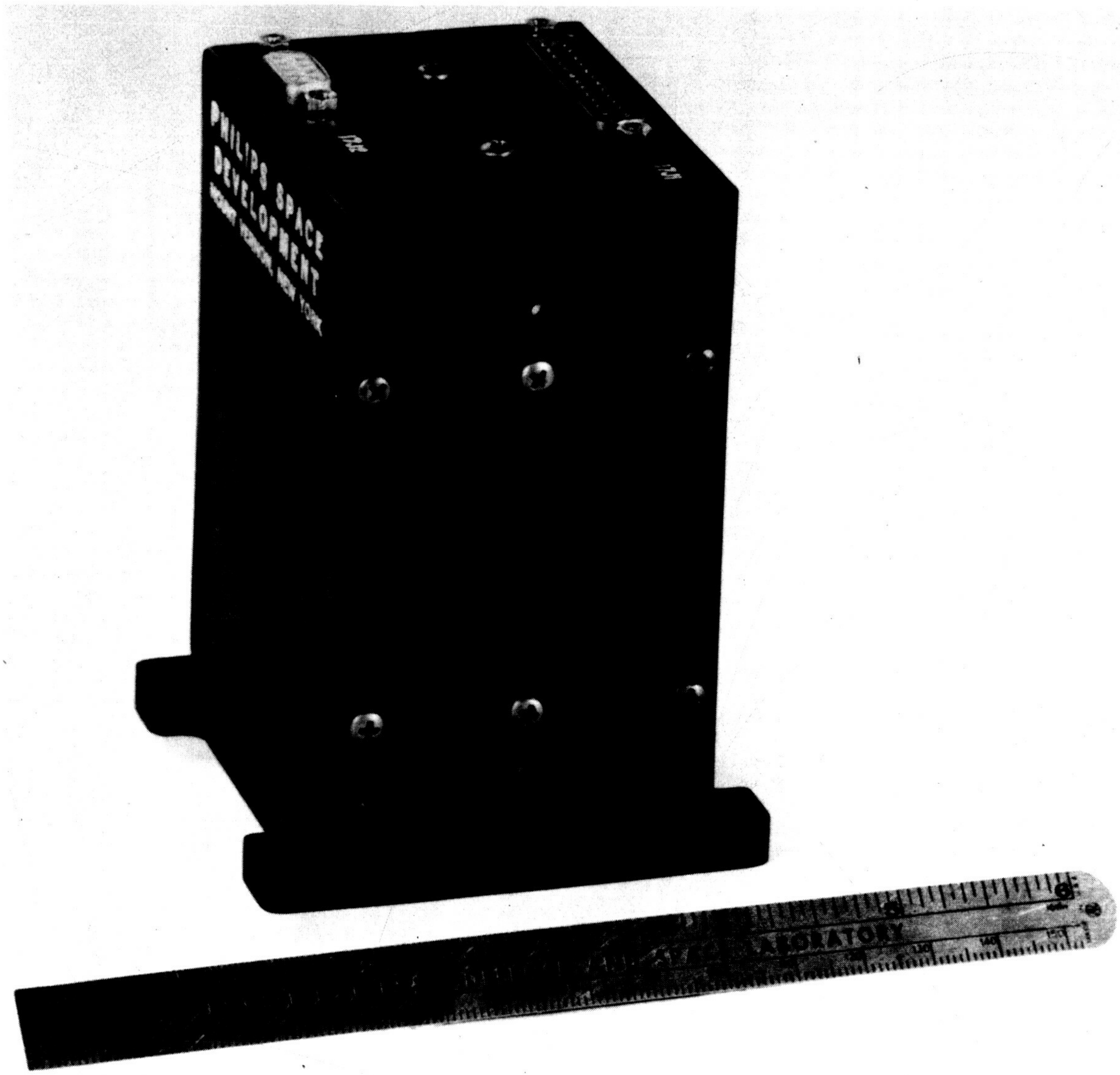


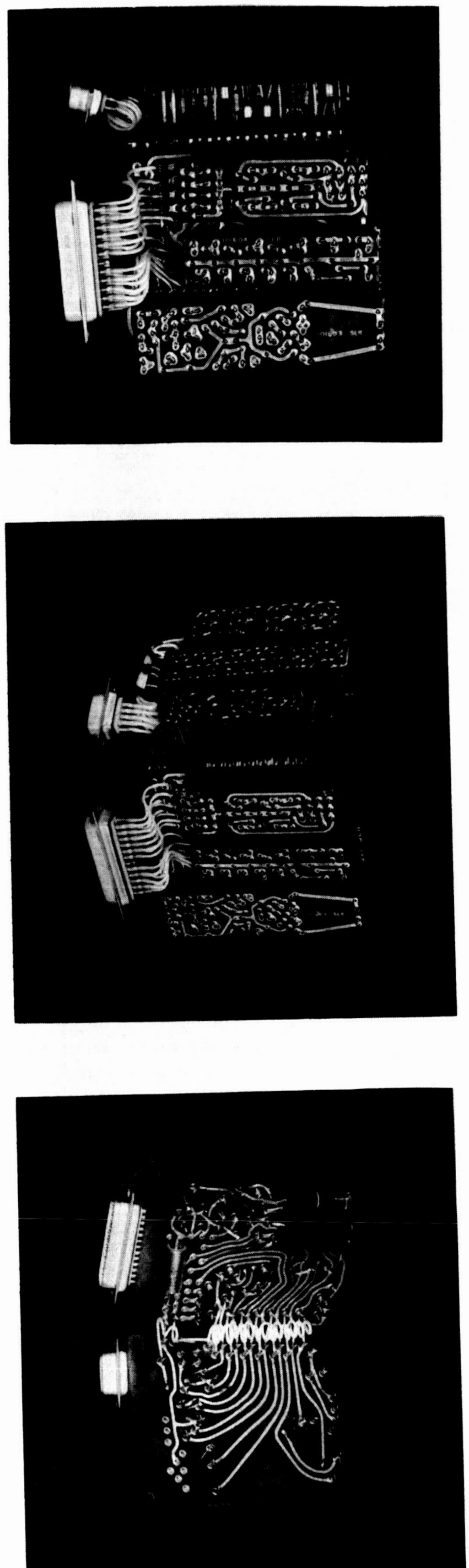
Figure 3-12: Model P-4/P-5 Compartment B Electronics Unit

soldered without direct application of heat to the module leads. In addition, the interwiring between the two distribution boards was simplified by the use of a row of terminals on the adjacent edges of the boards. By looping each interconnecting wire, a "hinge" was formed that enabled the two boards to be folded out (see Figure 3-13).

2) Housing Design. To allow room for the distribution board interconnecting wiring "hinge", the internal aluminum frame was made into a square "C" shape with the wiring loop in the open side of the "C". The connector plate and baseplate are attached to the top and bottom edges of the "C" frame, respectively, while the distribution board assemblies are fastened to the faces of the frame. A five-sided thin aluminum cover fits over the entire assembly, and a flange on the bottom edge of the cover is used to fasten the cover to the baseplate. Two additional screws secure the top of the cover to the connector plate.

During developmental vibration testing, two problems were encountered: fatique cracking of the cover flange along the bend line and a low resonant frequency of the complete unit which resulted in large displacements.

The solution was to incorporate a thin steel stiffener plate, on the vertical back edge of the "C" frame, slightly narrower than the width of the baseplate (see Figure 3-12). The cover was then made with four sides and no bottom flange, with the open side mating with the stiffner plate. A flange was



(c) (b) (a)

Figure 3-13: Compartment B Distribution Boards turned on the cover along the two edges of this open side. The cover fits over grooves in the stiffner plate and is screwed to this side and to the connector plate. This construction raised the resonant frequency, thereby reducing the displacement to an acceptable level.

3) <u>"No Trigger" Circuitry</u>. The motor command memory cordwood module was redesigned to incorporate the addition of the "no trigger" circuitry (see Paragraph 3.1.1).

3.3 Power Supply

3.3.1 Electrical

A block diagram of the Diffractometer Power Supply is shown in Figure 3-14. The supply delivers 25,000vdc, 2000vdc, 5v-7v p-p AC square wave, 6vdc, and 28vdc. It consists of two saturable core DC-AC inverters (a high voltage oscillator and a low voltage oscillator), a common emitter oscillator (2kv oscillator), their associated voltage multipliers, rectifiers, filters, and voltage regulators. In addition, the high voltage inverter has a command circuit associated with it to enable remote on-off control of the 25kv output.

The spacecraft 28vdc is delivered to the high voltage oscillator through a PNP transistor which is either cut-off or saturated, as determined by the state of a bistable multivibrator. The condition of this bistable is a function of the command pulse last received; hence the high voltage oscillator can be turned on or off via the command circuit.

The high voltage oscillator is a common collector saturable core DC-AC inverter delivering a 2500 volt peak square wave at 5kc to a 10X voltage multiplier. The output of the multiplier is 25,000vdc/1 ma (25 watts).

The low voltage oscillator receives a regulated voltage of approximately 21vdc as determined by the X-ray tube beam current. This oscillator is a common emitter saturable core DC-AC inverter with collector to base RC cross coupling; the feedback is thus not obtained in the standard fashion, i.e. by separate windings on the core. The frequency, however, is determined by the core from the standard Faraday equation, $E = (4N\emptyset f)\ 10^{-8}$, and is approximately 8kc. One output winding

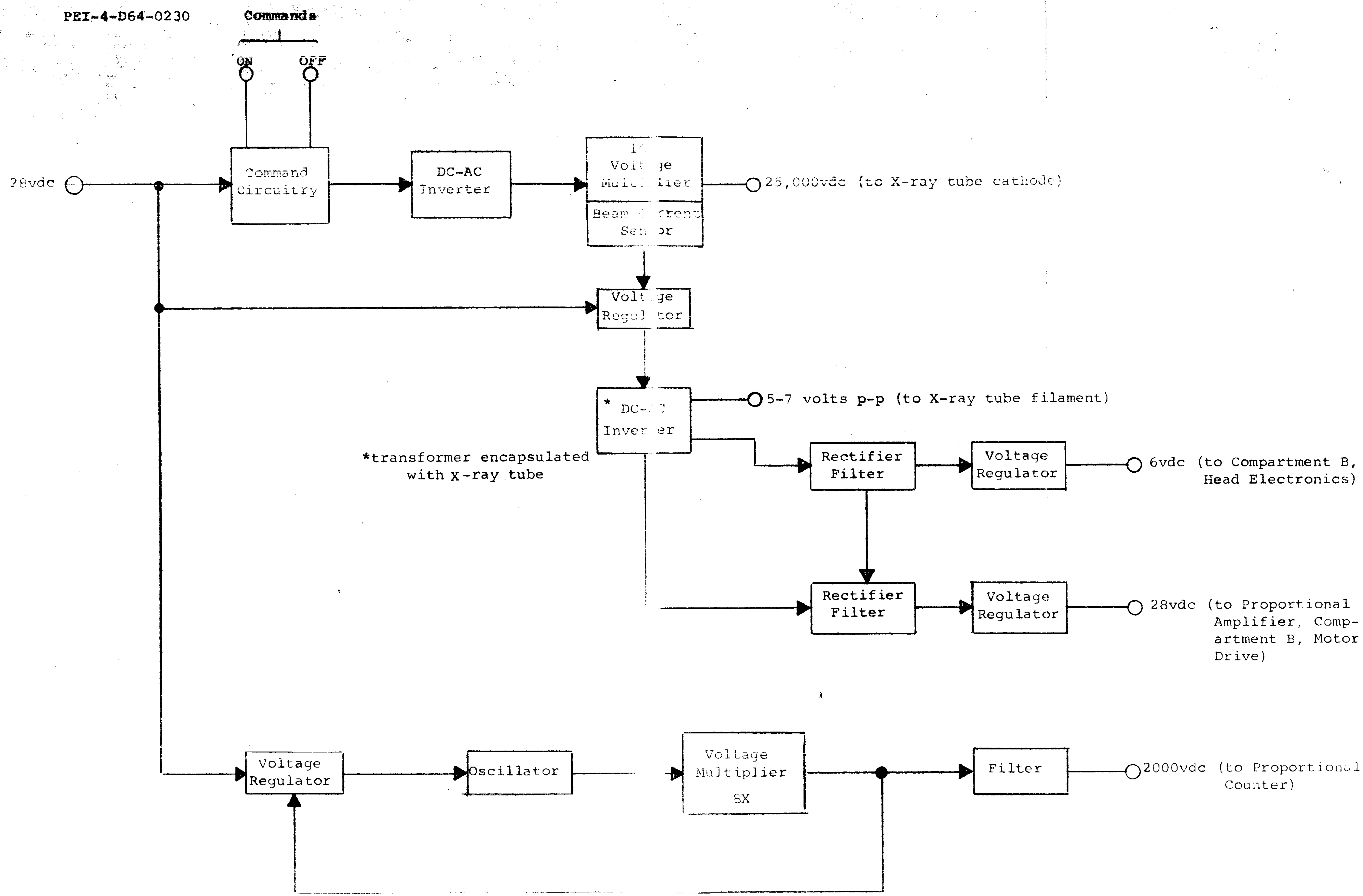


Figure 2-14: ... Supply Block Diagram

of this oscillator directly drives the X-ray tube filament; thus, the amplitude of this square wave (approximately 6v p-p) directly controls the magnitude of the X-ray tube beam current. A small DC voltage proportional to the beam current is generated in the high voltage 10X multiplier and controls a series voltage regulator feeding the low voltage oscillator. Hence, the beam current is regulated to 1 ma.

A second output from the low voltage oscillator drives a full wave bridge rectifier-filter and an associated voltage regulator (Zener diode) to obtain a 6vdc regulated output. The third winding is referenced to the 6vdc supply and drives a full wave rectifier-filter and a voltage regulator (Zener diode) to obtain a 28vdc regulated output.

The oscillator for the 2000vdc output is supplied with a regulated DC voltage, oscillates at approximately 100kc, and drives an 8X voltage multiplier. The output of the multiplier is filtered through a three-stage R-C network, giving 2000vdc. The multiplier output is sensed through a resistor divider which drives a differential amplifier of the voltage regulator.

A "no trigger" circuit (see Paragraph 3.1.1) was incorporated in the power supplies for Models P-4 and P-5.

3.3.2 Mechanical

The Model P-3 power supply was designed within the overall configuration prescribed by the instrument specification, but internally constructed for laboratory use. This unit complied with functional and configuration requirements and performance requirements in a thermal environment. However, no mechanical environmental tests were performed on this model. Models P-4 and P-5, however, were packaged to meet these latter requirements.

The power supply consists of five basic subassemblies:

1) mechanical structure
2) DC-AC inverters (2)
3) electronics board
4) 10X voltage multiplier block
5) 8X voltage multiplier

1) <u>Mechanical Structure</u>. The power supply measures (see Figures 3-15 and 3-16) 8" x 8" x 4" and weighs approximately 9 pounds. It is constructed of AZ31A magnesium with a ribbed baseplate welded to two opposite side walls. There are also two internal vertical plates, welded to the baseplate, for mounting the 2N1616 power transistors. In this manner, the power dissipating components are, in effect, connected to the baseplate which is the radiating surface when the unit is mounted on the spacecraft.

The two remaining side walls are screwed to the welded frame, forming the basic box structure. The top cover seats on flanges turned over on the side walls. This cover plate is provided with four 1/4-20 holes for mounting the unit on the spacecraft. These holes are equipped with Keensert type inserts for thread strength and to permit repeated screw insertions.

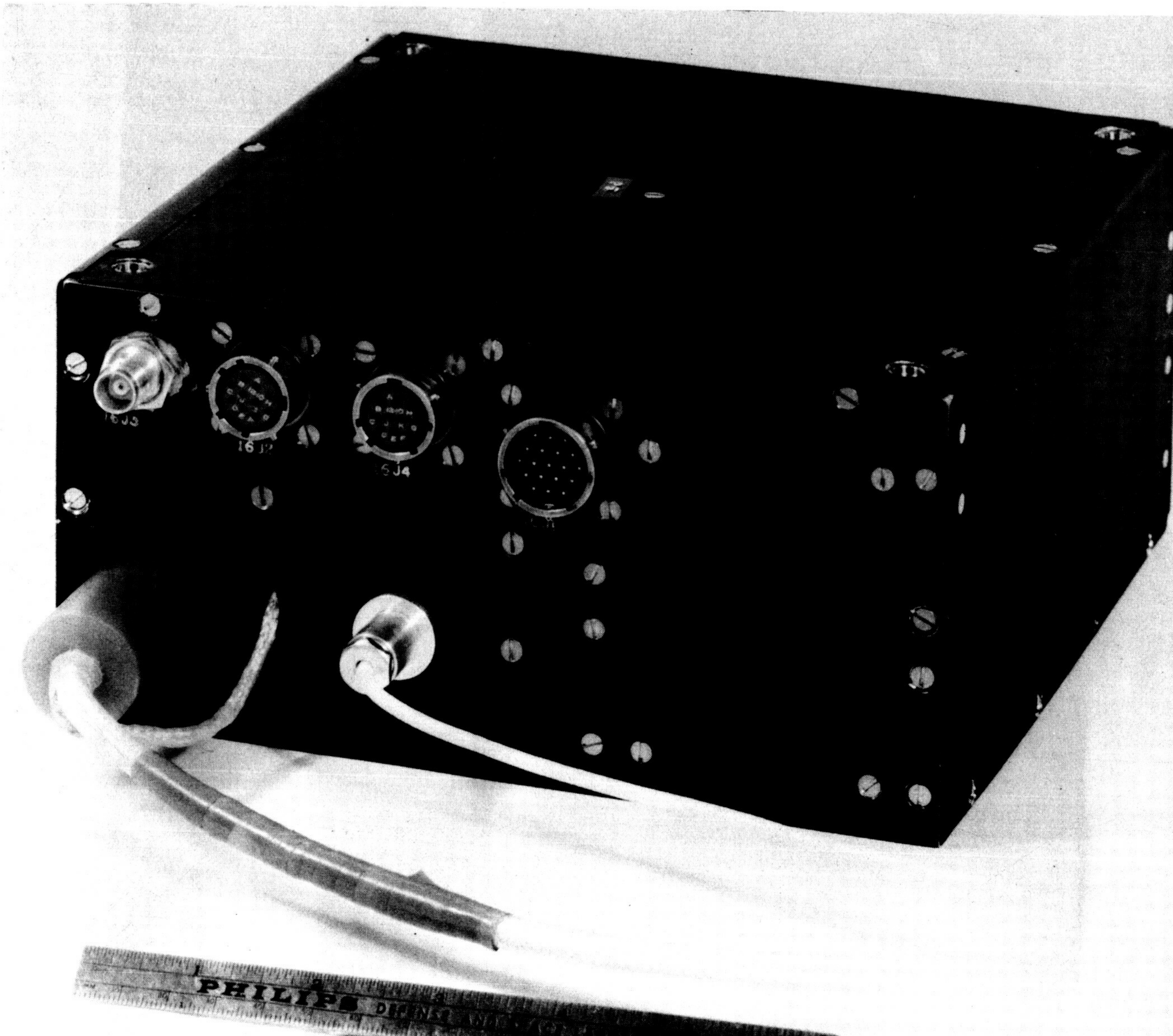


Figure 3-15: Model P-4/P-5 Diffractometer Power Supply

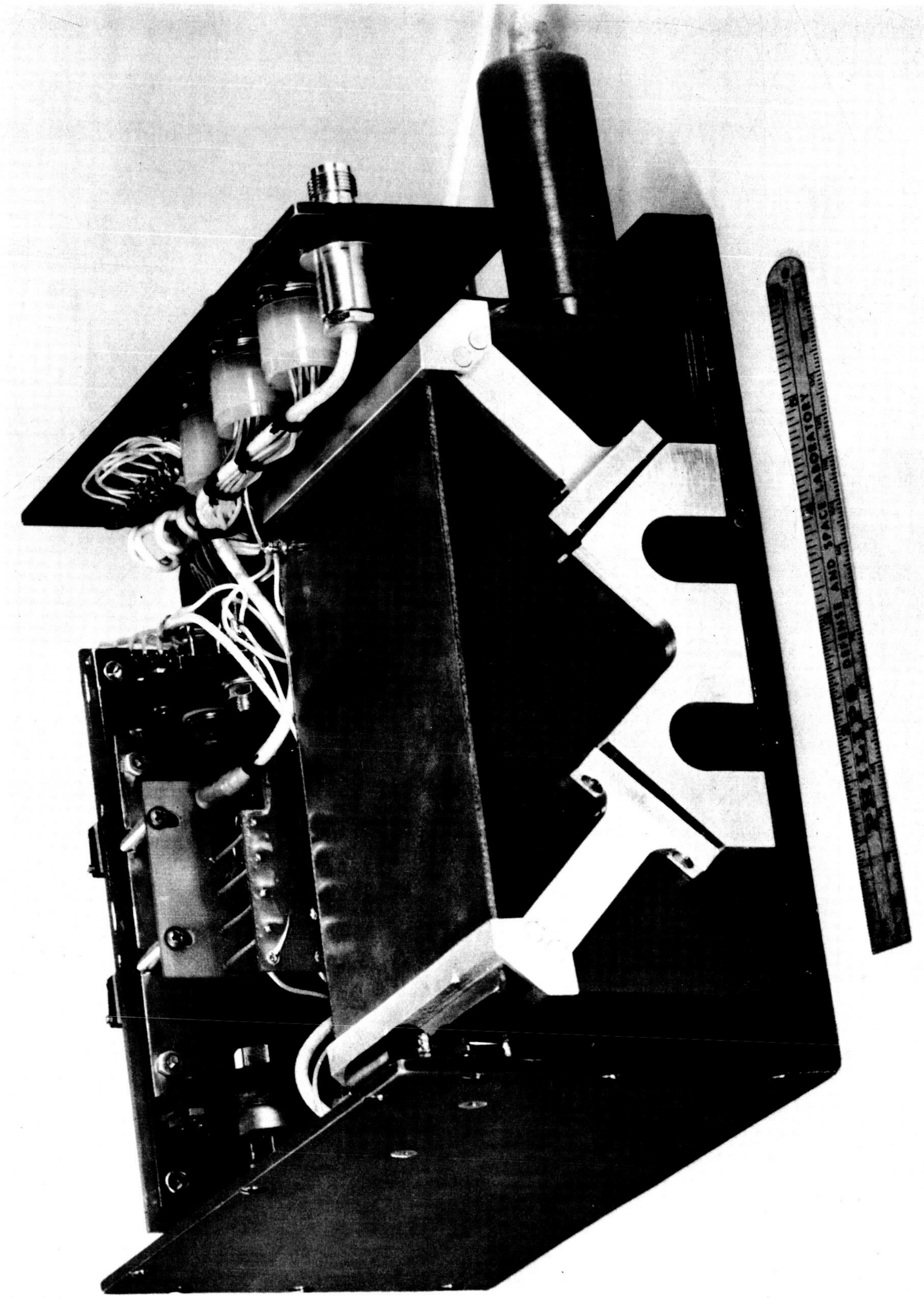


Figure 3-16: Model P-4/P-5 Diffractometer Power Supply (Uncovered, Showing 25kv Multiplier Block)

This structural arrangement permits removal of the two side walls and cover for servicing and removal of parts or subassemblies. The connectors are mounted to one of the fixed vertical walls so as not to disturb the internal harnessing when the unit is opened for servicing.

A thermal analysis of the power supply indicated the need for the following finishes (see Figure 3-17 for surface references) shown in Table 3-2.

Table 3-2: Model P-4/P-5 Power Supply Surface Finishes

Surface	Material	Surface Finish	Thermal Finish
A1'	Mg AZ31A	Dow No. 9	HAC White Paint
A2'	Mg AZ31A	Dow No. 9	HAC White Paint
A3'	Mg AZ31A	Dow No. 9	HAC White Paint
A4'	Mg AZ31A	Dow No. 9	HAC White Paint
A5'	Mg AZ31A	Dow No. 9	HAC White Paint
A6'	Mg AZ31A	Dow No. 9	Polished Mg
Interior	Mg AZ31A	Dow No. 9	Dow No. 9

2) DC-AC Inverters. The low and high voltage inverters (oscillators) were originally located in diagonally opposite corners of the power supply case. Both oscillators use two-piece cores (U and I cores) made by Ferroxcube Corporation of America, Numbers 1F10-3C5 and 1F10B4-3C5, respectively. A clamping arrangement was designed to capture the two pieces in three orthogonal axes. In addition, the bottom part of the clamp was secured to the baseplate and to the corner of two side plates.

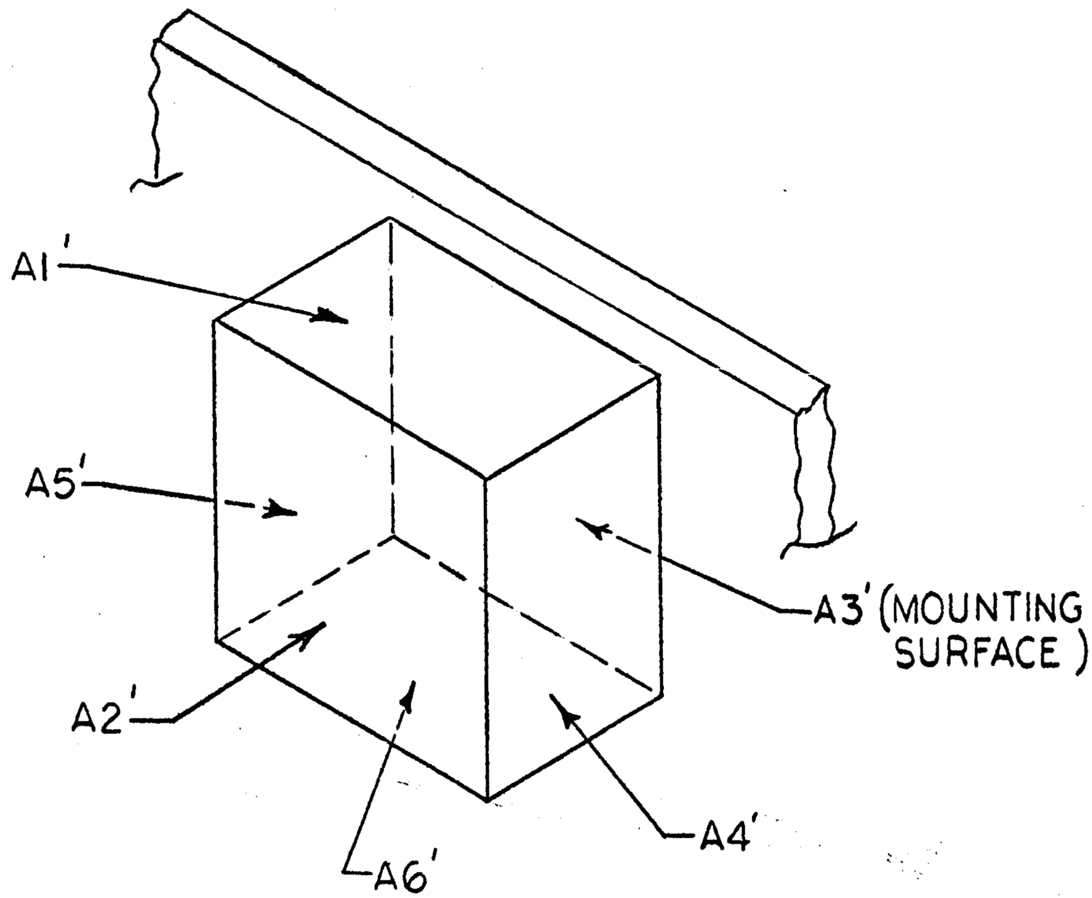


Figure 3-17: Model P-4/P-5 Power Supply Surface References

As described in Paragraph 3.1.2.3, the filament transformer of the low voltage oscillator was removed and incorporated into the encapsulated module of the X-ray tube.

3) Electronics Board. The electronics board (see Figure 3-18) is a two-sided flat printed circuit design. It is vertically mounted between, and perpendicular to, the two transistor mounting plates. The board faces one of the removable side walls to facilitate servicing, test, and adjustment.

Interconnection wires to the board are terminated at terminals located along the edge of the board. This keeps heat due to soldering away from the components.

4) 10X Voltage Multiplier Block. The 10X voltage multiplier block (2.5kv to 25kv) contains ten high voltage capacitors and associated resistors and diodes. It is located along one removable side wall of the power supply case and is clamped to the baseplate. The original design housed these components in a block made of multiple pieces of G-10. The individual parts of this block were fitted together and sealed using epoxy adhesive Shell 828. To provide additional arc-over supression, the block was covered with a wrap of 10 mil mylar sheeting. This design functioned well,and no high voltage failures were encountered.

Encapsulation of the X-ray tube (see Paragraph 3.1.2.3) made it apparent that the same technique should be applied to the voltage multiplier block. The block was designed in a

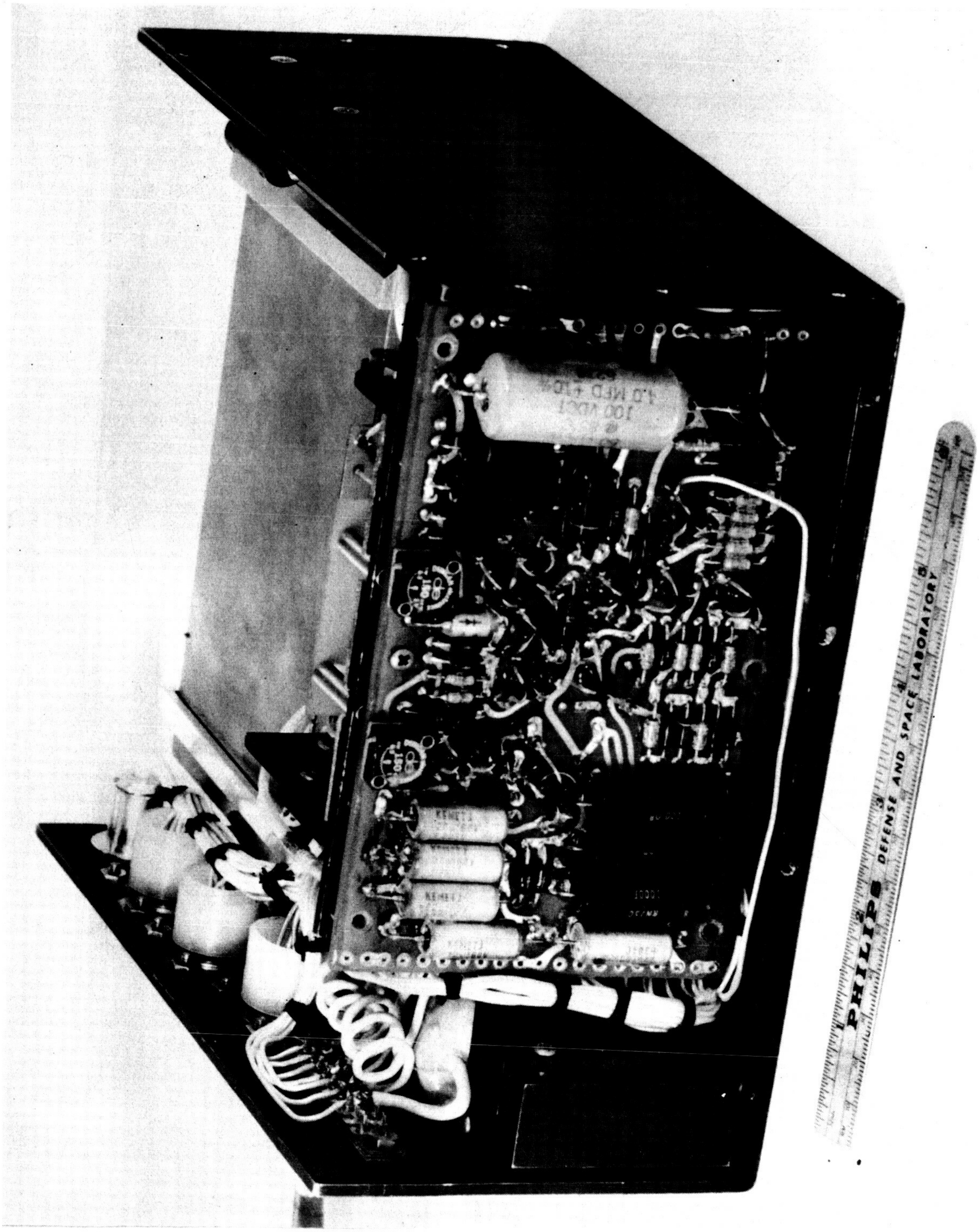
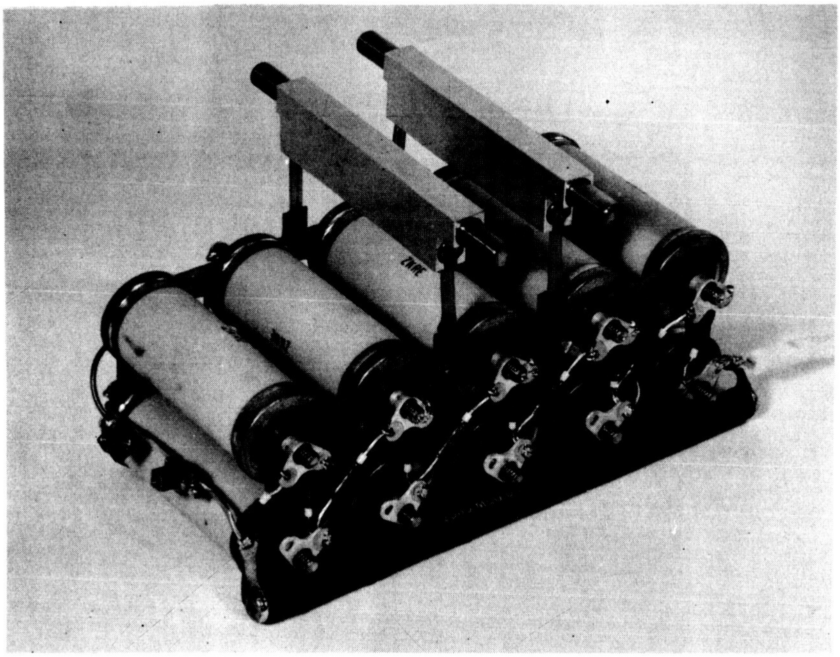


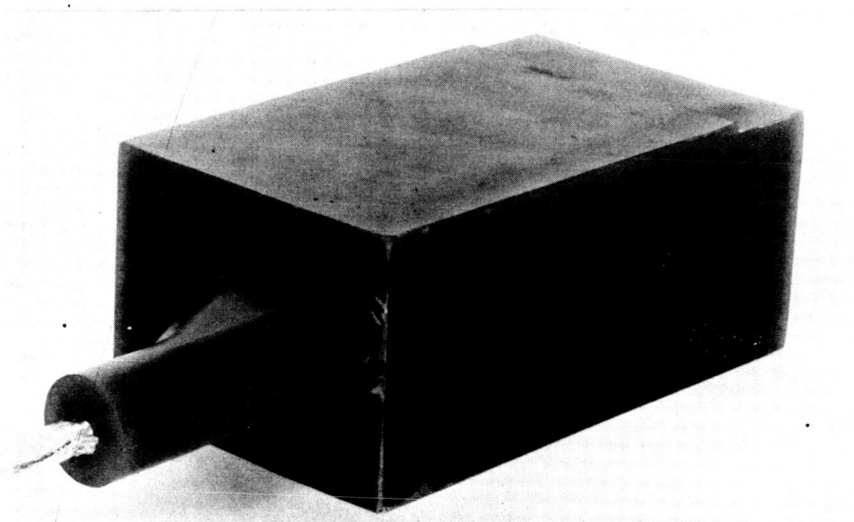
Figure 3-18: Model P-4/P-5 Diffractometer Power Supply
(Uncovered, Showing Printed Circuit Board)

configuration suitable for vacuum casting. The final design, before and after casting, is shown in Figure 3-19. The block is clamped to the base, as before, with the high voltage lead projecting from a cylindrical boot which protrudes from the power supply through a slot in one of the fixed side walls. This mounting permits the installation and removal of the block via the adjacent removable wall.

5) 8X Voltage Multiplier. This multiplier for the 2000vdc output is a printed circuit cordwood module located behind, and parallel to, the electronics board. An epoxy glass baseplate electrically insulates the multiplier from the power supply baseplate. Brackets,attached to the internal metal transistor plate, provide additional structural support.



(a) Before Encapsulation



(b) After Encapsulation

Figure 3-19: 10X Voltage Multiplier Block

3.4 Special Test Equipment

3.4.1 Electrical

The Diffractometer Control Test Panel (test rack) provides for testing of the system while it is operating. In addition, Compartment B and P-3 or P-3D power supplies may be tested together or individually.

The Command Panel contains all the necessary switches to operate the system, and the Power On switch energizes the system power supply. The "Threshold" switches select the threshold level of the Head electronics circuitry. The high voltage (25kv) is turned on or off by the "HV ON" and "HV OFF" switches; an "X RAYS ON" light indicates that the 25kv is on. An X-ray timer monitors total on-time of the 25kv, while a system timer registers the total on-time of the entire system. Four push-buttons command the goniometer motor into one of its four states: Forward, Fast Forward, Reverse, and Stop.

The Output Panel is supplied with the multiplex (MX) signal from the Head, monitored by an "MX IN" test point. This signal appears on the "Channel 1 Out" BNC connector and is attenuated by 0db and 40db as determined by the "Atten" switch. The angle marker output from Compartment B is also supplied to this panel and appears on the "∢-MKR" test point; this signal is converted to a 115v, 60cps pulse and appears on the "Recorder Solenoid" output jack.

The Test Point Panel contains twelve pin jack receptacles monitoring six test points in the power supply and six test points in the Head.

The Logic Control Test Panel is inoperative during system operation. When a Compartment B unit is plugged into the tray and the tray depressed, the unit is energized while any externally connected system is de-energized. Thus, this panel enables an individual Compartment B unit to be tested independently of the rest of the system. The Panel contains four "Motor Command" push-button switches and three push-buttons whose functions are to simulate microswitch commands normally supplied by the Head - ⚹-MKR, Home, and Reverse Commands. There are eleven test points on a recessed panel behind a flap and two test points below the tray. These points monitor only the Compartment B unit mounted on the tray.

The HV Monitor Panel is used with a P-3 or P-3D power supply. If a system is connected to the "HV Out" jack, then the panel monitors only the filament voltage (on a recessed meter visible via a prism). If the "HV Out" plug is removed, then a resistive load is internally switched across the 25kv output and monitored by the "HV Load Current" and "High Voltage" meters.

A recorder mounted in the rack monitors the various thermal sensors distributed throughout the system. It is presently wired to read 4 thermal sensors, 3 times per cycle. A constant current source associated with the recorder is mounted internally within the rack and external to the recorder.

The power supply, mounted in the bottom of the rack, supplies 28vdc to the system power supply and simulates the spacecraft DC supply.

3.4.2 Mechanical

The special test equipment is housed in a seven-foot JPL-supplied rack (see Figure 3-20). It contains the following items:

- Power Panel
- Temperature Recorder
- Command Panel
- Output Panel
- Test Point Panel
- Logic Control Test Panel
- High Voltage Monitor Panel
- Low Voltage Supply
- Connector Panel (rear-mounted)

These units were designed and constructed in accordance with good commercial practices, using standard laboratory units. The test rack has a slide-out tray equipped with a Compartment B harness assembly. When Compartment B unit is connected to the harness and the tray is pushed into the rack, the electrical interlock of the slide mechanism disconnects the Diffractometer Power Supply and supplies rack power only to Compartment B.

The High Voltage Monitor Panel was designed for Models P-3D and P-3. The Panel cannot be used for Models P-4 and P-5, since the high voltage output and input at the power supply and X-ray tube, respectively, are encapsulated (see Paragraph 3.1.2.3).

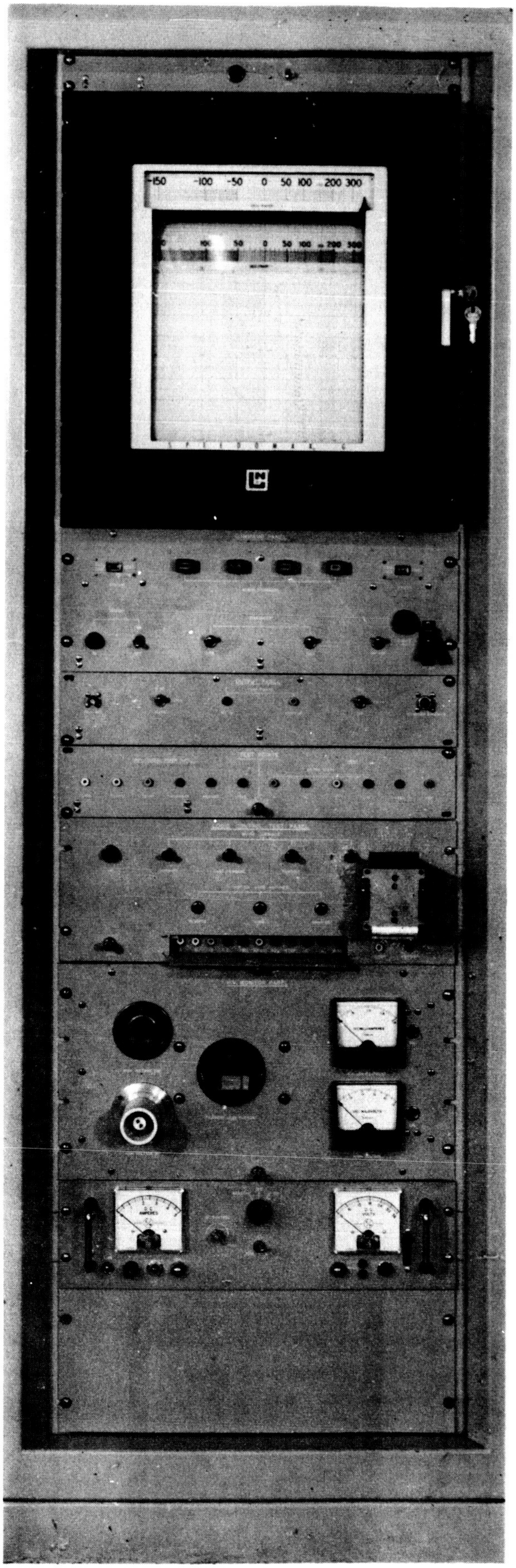


Figure 3-20: Diffractometer Control Test Panel

The cabling from the test rack to the Diffractometer is accomplished by three panel connectors located at the rear bottom of the rack. The rear of the rack is enclosed by a hinged door which has power line interlocks.

3.5 P-3 Thermal Model

Thermal models of the Head and Power Supply were delivered in accordance with JPL Contract #950158 Mod 9. These units were designed and fabricated for use in determining the steady-state operating temperature during the three spacecraft environmental phases: transit, lunar day, and lunar night. They provide the necessary elements to simulate both radiation and conduction coupling.

3.5.1 Head

The thermal model was designed to simulate the mechanical and thermal interfaces between the Head and the Surveyor spacecraft. Though the model was designed and fabricated for the P-3 version, no significant changes were made in the P-4 design that would invalidate the simulation provided by the P-3 model.

To accurately simulate the mechanical interface, a dust cover casting (PSD Drawing #101221, rejected for an internal structural defect) was used as the thermal model housing. The casting was machined to provide an interface in accordance with HAC Drawing #261877. A rejected goniometer casting was mounted in position inside the housing. This provided some thermal mass characteristics but was primarily used to give internal view factors between the heater elements and the external environment.

The individual heat dissipating elements were physically simulated by fabricated parts of comparable size and shape. Heater blankets were then affixed to these items to dissipate heat in accordance with the following table:

Table 3-3: Thermal Model Heaters - Head

No.	Item to be Simulated	Uniform Heat Dissipation @ 28vdc (watts)	Approx. Max. Temp. (°F)
1	X-Ray Tube	60.00	400
2	Motor	4.00	200
3	Head Electronics	0.67	200
4	Motor Drive Circuit	0.33	200

The heat dissipation figures represent twice the wattages dissipated by the actual components at 28vdc. This enables running at approximately 20vdc to achieve the proper heating effect.

The temperatures noted in Table 3-3 represent approximate temperatures as determined from the thermal analysis conducted at PEI. These temperatures were a conservative approach to the anticipated actual temperatures, allowing for surface finishes and the sun directly overhead at lunar noon.

The heaters were fabricated by Cox & Company of New York City to specifications supplied by PEI. The heaters were secured to the mechanical elements by an adhesive supplied by Cox and cured in a vacuum chamber maintained at approximately 10^{-6} torr. The electrical schematic for this unit is PSD Drawing #101556.

3.5.2 Power Supply

The Power Supply thermal model was designed and fabricated in a manner similar to the Head. That is, an actual power supply magnesium frame was used with appropriate welded members. Fabricated pieces simulated the two transformers, the 2kv module and the printed circuit board assembly. It was determined that there was no measurable heat dissipation from the 10-times multiplier module, therefore, simulation of that assembly was unnecessary. Heaters were provided as shown in Table 3-4.

Table 3-4: Thermal Model Heaters - Power Supply

No.	Item to be Simulated	Uniform Heat Dissipation @ 28vdc (watts)	Approx. Max. Temp. (°F)
1	Main Printed Circuit Board	2.00	200
2	2kv Module	0.07	200
3	Power Transistors (Left)	18.00	200
4	Power Transistors (Right)	34.00	200
5	Power Transformer	6.00	200
6	Filament Transformer	3.00	200

The heater elements were supplied by Cox & Company of New York City,and were designed for use in a hard vacuum environment. The figures for heat dissipation represent twice the heating power of the actual components. Nominal dissipation will occur at approximately 20vdc. The electrical schematic for this unit is PSD Drawing #101556.

4. SYSTEM TESTS

4.1 Developmental Tests

A series of developmental tests were performed to verify the Diffractometer instrument design. These tests were conducted on components, subassemblies, and assemblies. The tests included low and high temperature, shock, vibration, vacuum, and thermal vacuum.

4.1.1 Thermal Vacuum

Since thermal vacuum tests of the rotating portion of the Diffractometer Head are highly important, individual tests were performed on the motor and goniometer. The results of these tests are shown in Appendix A.

The thermal vacuum test of the motor was run as a component test with a fixture simulating the mounting and thermal mass of the goniometer. The input heat was introduced by a heater blanket attached to the mounting fixture which conducted the heat to the motor. The temperature was held at approximately +95°C in a vacuum environment of 2.8×10^{-6} mm Hg. The motor was run for six days and performed satisfactorily.

Although this test was made on a motor that had bearings impregnated with "Microseal" dry lubricated bearings (as contrasted with the "Bar Temp" bearings used on earlier models), the "Bar Temp" type unit was actually used in Models P-3, P-4, and P-5. This choice was based upon a confidence level established during the testing of the earlier models.

In addition, "Microseal" was considered too recent and, therefore, a process not qualified by experience.

The thermal vacuum test of the Head was conducted within a shroud that permitted control of the operating temperatures as per JPL Specification No. 31144. The shroud (within a bell jar) was equipped with heating lamps and a surrounding coil through which liquid nitrogen was passed. The temperatures of two sides of the Head were controlled by radiant coupling to the shroud, with the Head energized and scanning. The hot operating temperature was effectively controlled, but it was difficult to maintain -40°C for an extended period of time since the liquid nitrogen was blown by too fast.

4.1.2 Vibration

Vibration tests were conducted on the Diffractometer Head and Compartment B Electronics package in accordance with HAC Specification No. 224810 and PSD Specification No. D2032. The initial tests are documented in Belock Instrument Corporation (BIC) Report No. 1593-3 dated December 7, 1962. A second test was made at BIC on December 10, 1962, and documented in Report No. 1593-4. These two tests covered the sinusoidal vibration requirements of the applicable specifications. Random vibration tests were conducted at Associated Testing Laboratory (ATL) and documented in Report No. 40-3613. These three reports are included in Appendix B and C.

The structural responses to the applied forces led to the redesign of the Head and Compartment B, as previously noted in Paragraphs 3.1.2.2 and 3.2.2, respectively.

4.2 Acceptance Tests

The performance of Models P-4 and P-5 Diffractometers was tested according to Test Specification PDSL-F2016A. The test setup, test procedure, and test results are included in Appendix D, E, and F.

The acceptance tests included the following:

- Goniometer Speed Tests
- Operating Tests
- Reproducibility
- Measurement of Video Channel Output Characteristics
- Measurement of Angular Marker Channel Output Characteristics.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

During this developmental program, Philips Electronic Instruments has designed and developed six Lunar X-Ray Diffractometer prototypes (three models). These units were fabricated and delivered to JPL over the past two years; each unit underwent and passed acceptance tests and has been operating for varying periods of time at JPL. JPL design specifications were met by each model. The following table presents typical operating characteristics of models P-4 and P-5 when supplied with a properly prepared sample.

Table 5-1: Model P-4/P-5 Typical Performance Data

	Performance	Required
Peak intensity at 26° line of quartz	over 4000cps	2300cps min
Signal-to-background	90	27
Goniometer speed accuracy	0.5%	1%
Peak width at half height	0.17°	0.22° max
Symmetry	1.07	1.12
Reproducibility	0.03°	0.05°
Max deviation from peak count rate	2%	3%

An analysis of the results of this program has indicated the following possible areas of redesign:

a) Circuit redesign, selection of new and improved components, and repackaging of the Head, Compartment B Electronics unit, and the Power Supply into a single package.

b) Redesign of the goniometer (with sample holder fixed) to permit the Diffractometer to be used with or without a spacecraft sample processor and its transport mechanism.

5.2 Design Recommendation (a)

Since the present Diffractometer exceeds JPL specifications for intensity and resolution, it is possible to reduce the power consumption of the instrument without any significant degradation in performance. It is estimated that the present power requirements can be reduced by approximately 22 watts or more.

A savings in power of approximately 10 watts can be gained by reducing the X-ray tube current from 1.0ma to 0.6ma. The specifications call for a minimum of 2300 counts per second (cps) at the 26° line of quartz and for a signal-to-background ratio of at least 27. These requirements are exceeded by prototypes P-4 and P-5 which have in the order of 4000cps with a signal-to-background of 90. This means that the mean detectable limit has been decreased to 40% of that required by the specifications. A reduction of current to 0.6ma would still provide at least 2500cps with the signal-to-background still at 90, and thus, the instrument would have a mean detectable limit better than twice that required.

This decrease in X-ray tube power will result in lower operating temperatures and, therefore, increased tube life. This reduction in high voltage power will also result in an additional saving of 2 watts by the use of smaller, faster acting, less expensive transistors in the 25kv supply. These transistors dissipate less power and have a much higher gain than the ones presently being used.

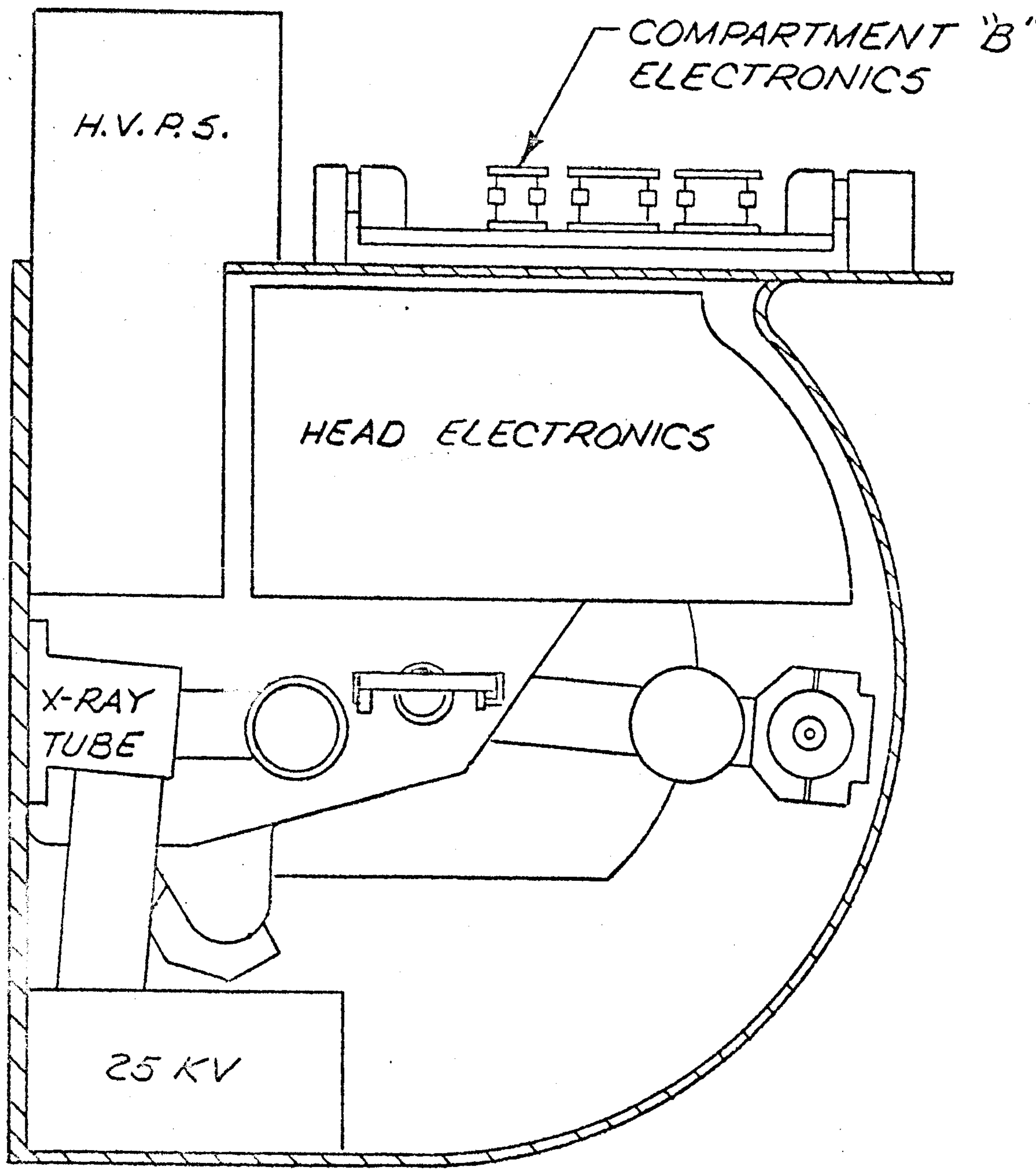


Figure 5-1: Integrated Diffractometer

An additional power saving of at least 10 watts can be obtained by using a new core material in the transformers of the 25kv and filament supplies. This would also result in a reduction in size and weight of the filament transformer.

The present diffractometer prototypes consist of three separate units - Head, Compartment B Electronics, and Power Supply. Integrating these three units into a common package (see Figure 5-1) would simplify mounting in the spacecraft, eliminate interconnecting cables, and reduce the size and weight of the instrument.

It is estimated that this repackaging will reduce the weight and size of the instrument from approximately 25 lbs. and 968 cu. in., respectively, to approximately 18.5 lbs. and 750 cu. in., respectively.

The X-ray tube will be rotated 180° and the mounting plate will be machined to maintain the existing optical axis. The X-ray tube, 10X multiplier, and filament transformer will be a single encapsulated unit. The volume formerly occupied by the X-ray tube and P-3 boron nitride connector will now contain the 2kv supply, high voltage oscillator, and associated circuitry. The top surface where the head connectors were previously mounted will now support all the printed circuit assemblies of the Compartment B Electronics package. This assembly will consist of a distribution board and six modules; the entire unit will plug into the head casting.

5.3 Design Recommendation (b)

By use of a goniometer designed to have its sample fixed, the previously mentioned spacecraft sample processor may be eliminated. In addition, this design will enable the Diffractometer to be used with such a processor, without any modification involved, should it be desired.

Two possible goniometer redesigns are: a) X-Ray Diffractometer with fixed sample, rotating X-ray tube, and rotating detector; and b) X-Ray Diffractometer with fixed sample, fixed X-ray tube, and rotating detector.

5.3.1 Goniometer Redesign (Sample Fixed, X-Ray Tube Rotating, Detector Rotating)

1) Diffractometer Optics. The Seemann-Bohlin parafocusing geometry (see Figure 5-2) requires the X-ray tube line source (F), receiving slit (G), and the curved sample holder (S) to all lie along the same circle. With such a geometry, all monochromatic X rays diffracted from identical planes of the sample crystals will be focused at the same point.

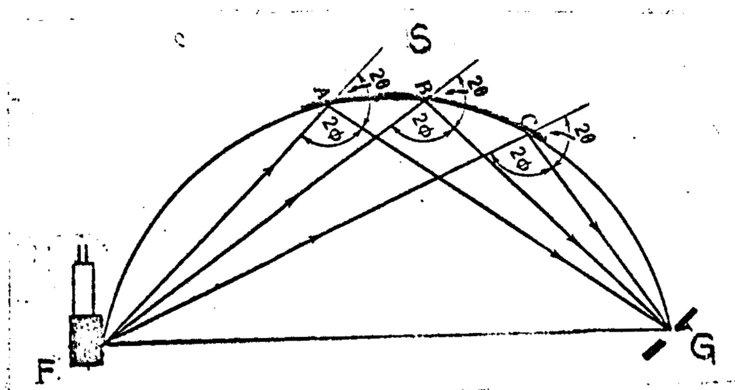


Figure 5-2: Seemann-Bohlin Parafocusing Geometry

Replacing the correctly curved sample surface with either a tangential flat surface or a tangential surface of different curvature, will result in an out-of-focus diffracted beam. However, if the irradiated sample surface is not too long, the beam will be only slightly out of focus.

The prototype diffractometer geometry (see Figure 5-3) maintains a θ, 2θ relationship between the sample holder rotation and the receiving slit rotation, with the center of the sample holder shaft as the axis of rotation. Thus, the radius of the Seemann-Bohlin parafocusing circle is continuously varied. There is only one angle (2θ) of precise focusing with a curved sample surface - when the radius of curvature of the sample surface is twice the radius of the circle on which the receiving slit moves. This 2θ angle of precise focusing is 29.3°.

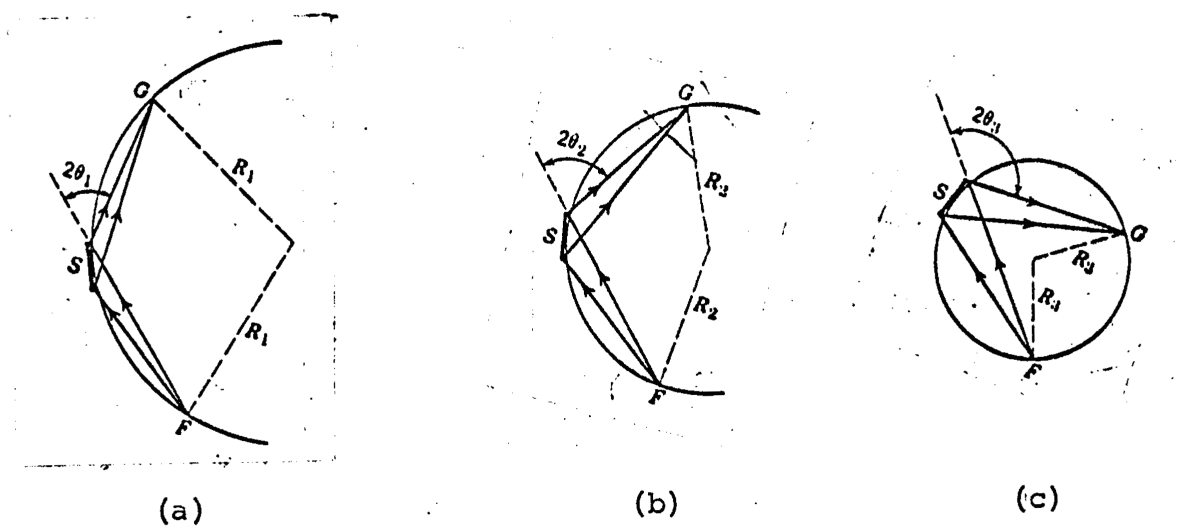


Figure 5-3: Prototype Diffractometer Geometry

If the curved sample were now to be fixed and the detector still rotated as before, then rotation of the X-ray tube would maintain the Seemann-Bohlin relationship. For this configuration, resolution and intensity would not be affected. However, if the surface of the sample were to be flat, there would be a degradation of the resolution especially at the angle of precise focusing. This degradation can be minimized by limiting the aperture angle so that a smaller area of the sample is irradiated; however, this would result in a decrease in intensity.

The present diffractometer, with a 25kv and 1 ma X-ray tube and 0.009 inch receiving slit, records the 1.01 line of quartz with a resolution of 0.186° (half-width) at a peak count rate of approximately 4200cps. Assuming the same resolution as that for a curved sample (obtained by decreasing the X-ray source aperture), it is estimated that the output intensity in the case of the flat sample will decrease by a factor of three. Thus, with the X-ray tube at 25kv, 1 ma, the intensity would be approximately 1400cps with a resolution of 0.186° for the 1.01 quartz line.

2) <u>Instrument Description</u>. This goniometer redesign involves the following two basic motions:

- The X-ray tube and detector must traverse complementary arcs along a focusing circle (3.347" radius).
- The X-ray tube and detector windows must lie on this circle and be directed at the sample for every position along the circular path.

These functions can be accomplished by the design shown in the diagram, Figure 5-4. The weight and volume of a single instrument package employing this design is estimated to be 17 lbs. and 750 cu. in., respectively.

5.3.2 Goniometer Redesign (Sample Fixed, X-Ray Tube Fixed, Detector Rotating)

1) Diffractometer Optics. To maintain the correct Seemann-Bohlin parafocusing geometry for this configuration, the receiving slit must move along a constant radius Seemann-Bohlin focusing circle (See Figure 5-5) and remain perpendicular to the central rays from the sample surface. The receiving slit, therefore, moves along a path varying in distance from the sample surface. Use of a flat sample surface, instead of a curved one, will have the same effect upon resolution and intensity as the design previously discussed in Paragraph 5.2.

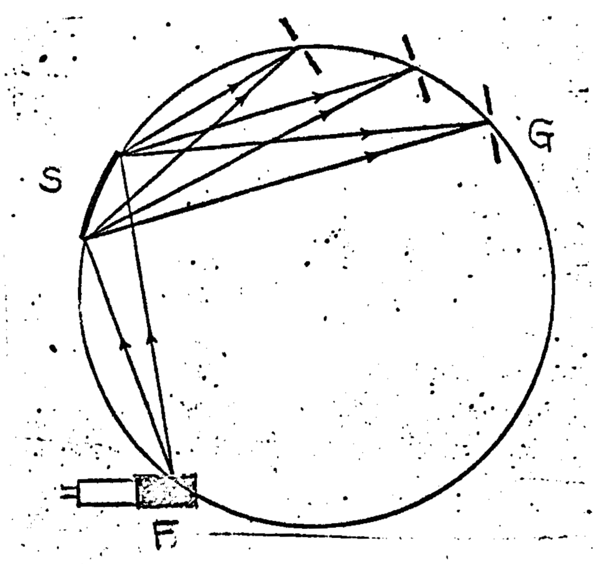


Figure 5-5: Prototype Diffractometer Geometry

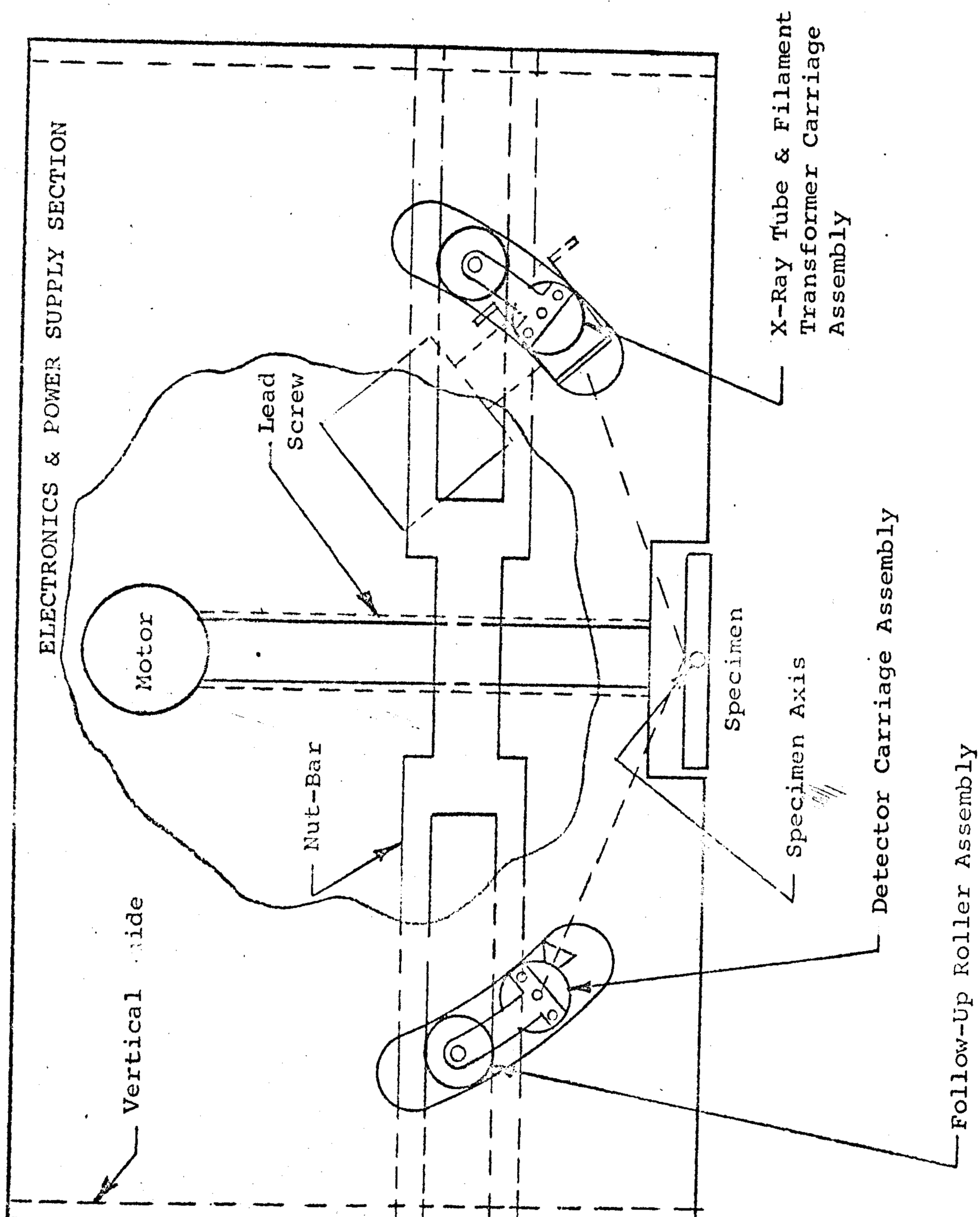


Figure 5-4: Mechanism Diagram

2) Instrument Description. A goniometer of this design involves the following:

- A stationary X-ray tube whose window is located on the focusing circle
- A stationary sample located on the focusing circle
- A detector which travels along focusing circle and whose window is constantly directed at the sample.

Figure 5-6 is a diagram of such a mechanism. The weight and volume of a single instrument package using this goniometer design is estimated to be 16 lbs. and 1000 cu.in., respectively.

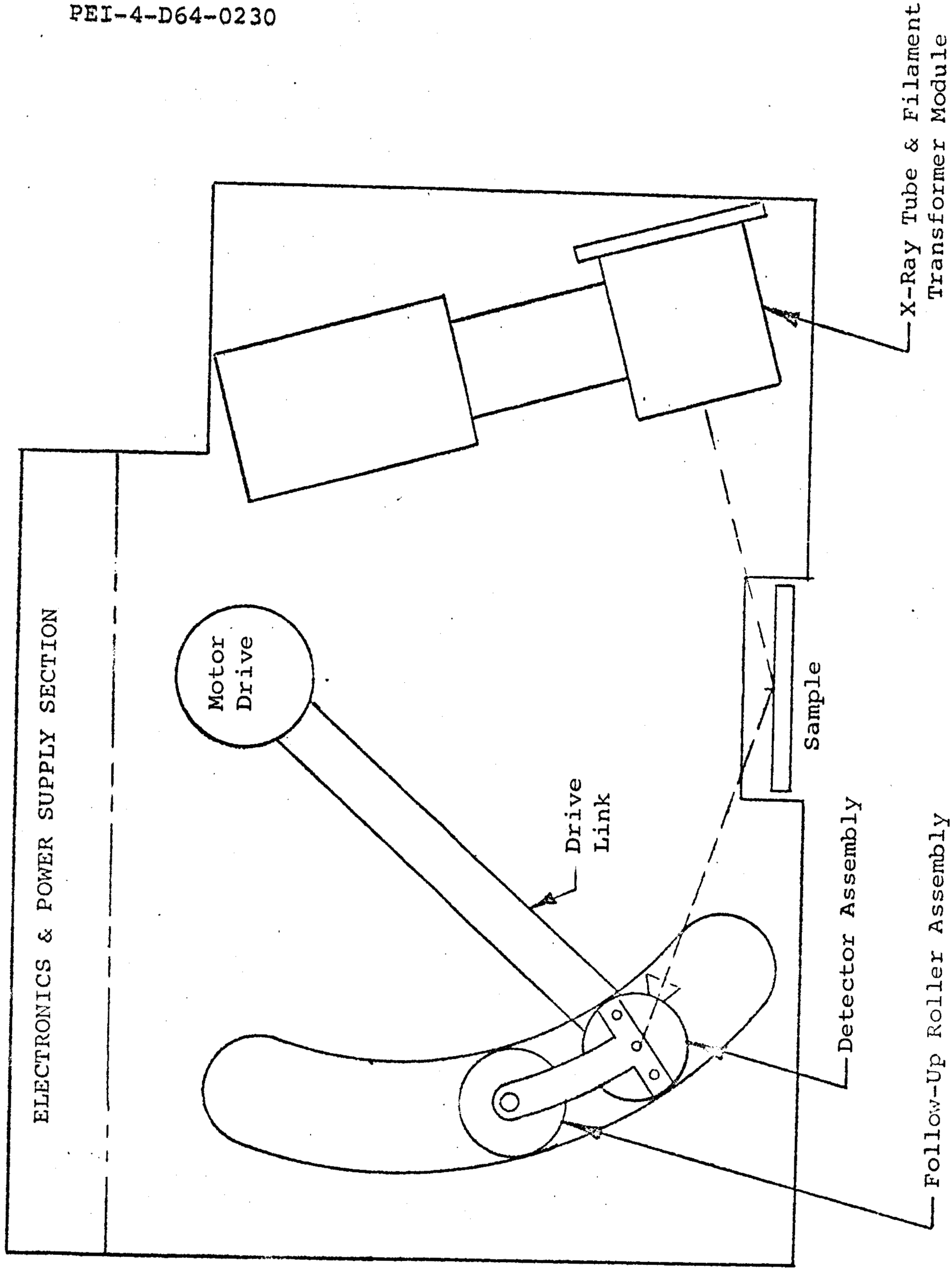


Figure 5-6: Mechanism Diagram

APPENDIX A

THERMAL VACUUM DEVELOPMENTAL TESTS
(Diffractometer Head and Stepper Motor)

#101

PSD TEST INFORMATION SHEET

ENVIRONMENTAL LAB

1. Description of Test Temperature Vacuum Test STEPPER MOTOR

2. Instrument DIFFRACTOMETER D
3. Subassembly STEPPER MOTOR # 465
4. Test No. 1 In a series of 1
5. Test Engineer H. VAN KUYK
6. Technicians 1. J. KOLKOWSKY.
2.
3.
7. JPL Observer none *

8. Date 9/6/62
9. Start Time 2 p.m 8/31/62
10. Stop Time 9 a.m 9/6/62
11. Temperature * * °C.
12. Barometric Pressure * * mm Hg

Quality Assurance [signature]

13. Test Equipment Used

Name	Make	Model	PSD Serial #	Calibration Date
VACUUM SYSTEM	VEECO		52	1/62 †
Temperature Potentiometer	L&N	cat# 8693	124	1/62 †
Square Wave Generator	hp	211A	517	1/62 †
motor drive circuit	P.S.D.	TEST LAB MODEL		—
ELECTRONIC COUNTER	hp	521G	131	1/62 †
Special test bracket, heated by silicone pad connected to variac				

14. Problems Encountered and Comments STEPPER MOTOR, part # 774-8-900-125 serial # 465 ran for 6 days in vacuum of 2.7×10^{-5} mm Hg ~~and~~ while mounted to a aluminum plate which was kept at 95°C. No problems were encountered.

15. Approved:

Test Engineer [signature] Date 9/6/62

JPL Observer ____________ Date ____________

Quality Assurance [signature] Date 7 SEP 1962

† Equipment to be calibrated as soon as Instrument Control System is completed and calibrations started again.

* Mr. F. Robason of J.P.L. saw the test set up on 9/5/62

101

PHILIPS SPACE DEVELOPMENT COMPONENT TEST

ITEM # 101 DESCRIPTION TEMPERATURE-VACUUM TEST OF STEPPERMOTOR
part # 774-8-900-125; Serial # 465;
MANUFACTURER: AUTOMATION DEVELOPMENT CO.

TEST	SPEC	PRE-TEST DATA	TEST RESULTS	DATE
THE STEPPERMOTOR HAS THE CONVENTIONAL BEARINGS. HOWEVER, THEY ARE IMPREGNATED WITH "MICROSEAL" (MICROSEAL PRODUCTS CO.). THE MOTOR WAS MOUNTED ON A LARGE ALUMINUM TEST FIXTURE, USING THE SAME MOUNTING METHOD AS IS USED IN DIFFRACTOMETER D. (P-3) THE FIXTURE + MOTOR WERE PLACED IN A VACUUM BELL JAR. THE FIXTURE WAS HEATED BY PUTTING IT ON A SILICONE RUBBER PAD, CONTAINING A RESISTANCE HEATING ELEMENT. THE TEMPERATURE OF THE FIXTURE WAS MEASURED WITH A CU-CONST. THERMOCOUPLE AND WAS HELD BETWEEN 90°C AND 100°C. THE TEMPERATURE OF THE MOTOR WAS ALSO MEASURED WITH A CU-CONST COUPLE, MOUNTED ON THE SIDE. AT ALL TIMES THE MOTOR WAS FOUND TO BE 16 to 17°C HIGHER IN TEMPERATURE THAN THE FIXTURE. THE MOTOR RAN ALL THE TIME, BEING DRIVEN BY THE LAB'S DRIVE CIRCUIT. THE CIRCUIT WAS CONNECTED TO A SQ. WAVE GENERATOR WHICH OSCILLATED AT 50 p.p.s. THE FREQENCY WAS MEASURED WITH AN ELEC. COUNTER. THE VACUUM OBTAINED IN THE BELL JAR WAS 2.8×10^{-5} mm Hg. THE VACUUM WAS MEASURED WITH AN ION GAUGE. THE MOTOR WAS SUBJECTED TO THESE ENVIRONMENTS FOR 140 HRS. IT WAS OPERATING ALL THE TIME, EXCEPT FOR A PERIOD OF ABOUT 24 HRS, DUE TO THE FACT THAT A BATTERY HAD RUN DOWN. NO PROBLEMS WERE ENCOUNTERED. THE MOTOR PASSED THE TEST SUCCESSFULLY.				8/31/62 to 9/6/62

HVK 9/6/62

PSD TEST INFORMATION SHEET

1. Description of Test "A" HIGH TEMP / "B" LOW TEMP / VACUUM TEST
OPERATIONAL

2. Instrument DIFFRACTOMETER P3D
3. Subassembly DIFFRACTOMETER HEAD
4. Test No.____ In a series of ____
5. Test Engineer DMcALLEY MONROE FISH
6. Technicians 1. ____
2. ____
3. ____
7. JPL Observer ____

8. Date 3-20-63
9. Start Time 3-20-63
10. Stop Time 3-22-63
11. Temperature 24 °C.
12. Barometric Pressure NORMAL mm Hg

Quality Assurance ____

13. Test Equipment Used

Name	Make	Model	Serial #	Calibration Date
VACUUM SYSTEM	PHILIPS			
TEMP SHROUD	" "			
TEMP CONTROL	SYMPTROL	PR	R49734	
POWER SUPPLY 28V	PHILIPS	PE4804		
" " " " 1000V	PHILIPS	PW4025		
" " " " 25KV	PHILIPS			
ELECTRONIC CIRCUIT PANEL	PHILIPS	PSD #A95		

14. Problems Encountered and Comments ____

15. Approved:

Test Engineers David McAlley Date 3-22-63

JPL Observer ____ Date ____

Quality Assurance ____ Date ____

#135 A-B

A4

3-14-63

THERMO - VACUUM TEST ON DIFFRACTOMETER P.D.

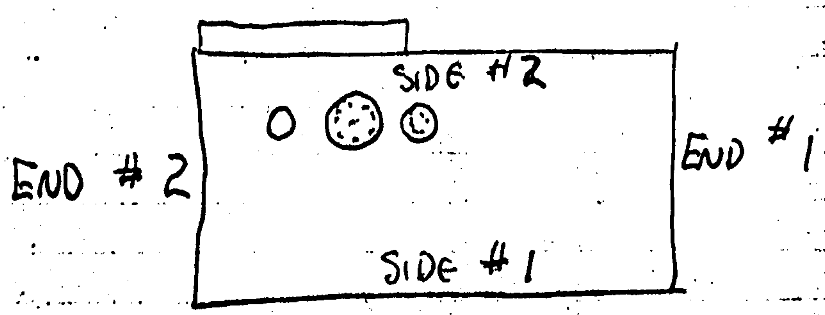
THERMOCOUPLES INSTALLED. (COPPER CONSTANTAN)

- #1 SIDE #2
- 2 END #1
- 3 END #2
- 4 BOTTOM
- 5 TOP (CONNECTOR)
- 6 MOTOR BODY
- 7 CU BASE OF X-RAY TUBE.
- 8 PROP COUNTER BODY
- 9 TOP BOARD
- 10 SAMPLE HOLDER FRAME
- 11 MAIN ELECTRONICS BOARD.

CONTROL THERMOCOUPLES IRON CONSTANTAN.

A - SIDE OF SHROUD (+210°F CONTROL)

B - SIDE #2 OF DIFF (-40°F CONTROL)



TOP VIEW OF DIFF. HEAD

3-21-63 P3D DIFF HEAD LOW TEMP TEST ①

COOLING OFF TEMPERATURE

AM.	10 45	11.00	11.15	11.30	11.45	12.00	12.15	12.30	1PM	—	1.30	1.45	2.00	2.15	2.30
THERMO	0	15	30	45	60	75	90	105	120	135	150	165	180	195	210
*															
1			34.0	30.0	17.0	6.0	-1.0	-8.0	-15.0	—	-29.0	-35.0	-39.0	-43.0	-46.0
2			37.5	34.0	22.0	13.0	6.0	0	-11.0	—	-24.0	-30.0	-35.0	-39.0	-42.0
3			30.0	24.0	8.0	0	-7.0	-13.0	-20.0	—	-33.0	-38.0	-43.0	-47.0	-49.0
4			35.0	31.0	18.0	10.0	2.0	-5.0	-12.0	—	-27.0	-32.0	-38.0	-42.0	-44.0
5			33.0	28.0	12.0	2.0	-6.0	-12.0	-20.0	-	-34.0	-38.0	-43.0	-47.0	-50.0
6			39.0	36.0	25.0	16.0	8.0	2.0	-5.0	-	-22.0	-27.0	-33.0	-37.0	-40.0
7			42.0	38.0	26.0	18.0	9.0	3.0	-6.0	-	-21.0	-27.0	-33.0	-37.0	-40.0
8			40.0	39.0	31.0	24.0	18.0	13.0	6.0	—	-10.0	-15.0	-21.0	-25.0	-28.0
9			42.0	40.0	28.0	20.0	12.0	7.0	-2.0	—	-18.0	-24.0	-30.0	-35.0	-38.0
10			42.0	40.0	30.0	22.0	16.0	10.0	3.0	-	-13.0	-19.0	-25.0	-29.0	-33.0
11			40.0	39.0	29.0	21.0	14.0	9.0	1.0	—	-15.0	-21.0	-27.0	-31.0	-34.0
13			34.0	30.0	19.0	9.0	3.0	-3.0	-12.0	—	-26.0	-32.0	-36.0	-40.0	-43.0

TEMPERATURES °C VACUUM 2×10^{-7}

SEE CHARTS FOR RESULTS OF TEST

135-B

A6

3-21-63 P3D DIFF HEAD LOW TEMP / VACUUM

(2)

2:[illegible]	3:00	3:15	3:30	3:45	4:00	4:15	4:30	4:45 PM		3-22-63 8:45 AM	9 AM	9:15	9:30	9:45	10:00	10:15
225	240	255	270	285	300	315	330	345								
						25KV 1MA					25KV 1MA					
-[illegible]9.0	-52.0	-50.0	-49.0	-46.0	-43.0	-45.0	-42.0	-41.0	ALL POWER AND LIQUID AIR OFF	-20.0	-16.0	-10.0	-1.0	+4.0	+9.0	+14.0
-45.0	-48.0	-52.0	-54.0	-53.0	-52.0	-46.0	-32.0	-19.0		-22.0	-4.0	+6.0	+18.0	+24.0	+29.0	+34.0
-[illegible]2.0	-55.0	-57.0	-55.0	-53.0	-51.0	-52.0	-50.0	-46.0		-19.0	-17.0	-13.0	-5.0	0	+5.0	+9.0
-[illegible]7.0	-50.0	-54.0	-53.0	-50.0	-49.0	-49.0	-42.0	-37.0		-21.0	-14.0	-7.0	+2.0	+7.0	+13.0	+17.0
-57.0	-55.0	-58.0	-59.0	-56.0	-54.0	-55.0	-52.0	-47.0		-20.0	-16.0	-11.0	-2.0	+2.0	+8.0	+12.0
-43.0	-46.0	-50.0	-52.0	-51.0	-50.0	-50.0	-45.0	-36.0		-22.0	-17.0	-11.0	+1.0	+6.0	+13.0	+18.0
-[illegible]3.0	-46.0	-50.0	-52.0	-52.0	-51.0	-23.0	-6.0	+8.0		-22.0	+17.0	+28.0	+40.0	+46.0	+50.0	+55.0
[illegible]	-35.0	-39.0	-42.0	-43.0	-44.0	-45.0	-44.0	-44.0		-25.0	-23.0	-20.0	-14.0	-10.0	-7.0	+1.0
-41.0	-44.0	-48.0	-51.0	-52.0	-51.0	-52.0	-48.0	-38.0		-22.0	-19.0	-11.0	-1.0	+5.0	+12.0	+17.0
-[illegible]6.0	-39.0	-42.0	-45.0	-45.0	-46.0	-46.0	-44.0	-41.0		-25.0	-21.0	-17.0	-10.0	-4.0	+2.0	+8.0
-[illegible]8.0	-41.0	-45.0	-48.0	-48.0	-49.0	-48.0	-47.0	-43.0		-19.0	-19.0	-16.0	-8.0	-4.0	+2.0	+7.0
						MOTOR SLUGGISH COUNTS LOW					COUNTS LOW				COUNTS INCREASED 30%	
															2100	2800
-45.0	-47.0	-47.0	-45.0	-43.0	41.0	-40.0	-40.0	-39.0		-16.0	-12.0	-6.0	+2.0	+6.0	+10.0	+14.0

VACUUM 2×10^{-7}

OUT OF LIQUID AIR — TURNED ON LAMPS

INSTALLED IN TANK

#1350

3-22-63 (3)

	—	2:15	2:30	2:45	3:00	3:15						
	THERMO #		(25KV 1MA			)						
+16.0	1	-44	-42	-41	-38	-36						
+37.0	2	-43	-41	-28	-17	-12						
+12.0	3	-49	-48	-48	-45	-42						
+10.0	4	-45	-44	-41	-34	-29						
+15.0	5	-49	-49	-49	-44	-41						
+21.0	6	-41	-42	-39	-32	-32						
+59.0	7	-41	-33	-1	+11	+13						
+5[illegible]	8	-30	-32	-34	-35	-35						
+20.0	9	-39	-40	-40	-35	-29						
+[illegible]2.0	10	-34	-35	-35	-35	-33						
+12.0	11	-36	-37	-38	-37	-35	-40	-45	-50	-55	-60	-65
			(X RAY ON PWR ON			)						
2[illegible]00	COUNTS		1840									
+16.0		-41	-42	-40	-38	-34						

TEST DISCONTINUED AT THIS POINT

CONTINUED IN TENNEY CHAMBER (3-29-63)

(LIQUID AIR TANK INSTALLED COOLING OFF TO -40°C)

ALL EQUIPMENT OFF

#135BO

A8

3-20-63

TEMP °C — TIME MINS — DIFF P3-D

HIGH TEMP - VACUUM

	3PM 0	15	30	45	60	75	* 90	105	120	135	150
		17KV ½MA	23KV 1MA	23KV 1MA	23KV 1MA	23KV 1MA	23KV 1MA	25KV 1MA	25KV 1MA		
1	96.5	96.0	96.5	97.0	97.5	98.0	98.0	98.0	98.0		
2	97.0	101.0	108.5	111.0	114.0	116.0	117.0	117.5	117.5		
3	96.5	94.0	93.5	93.5	94.0	94.0	93.5	93.5	93.5		
4	97.0	96.5	97.0	99.0	100.0	101.0	101.0	101.5	101.5		
5	97.0	95.0	94.0	94.5	95.0	95.0	94.5	95.0	95.0		
6	97.0	97.0	98.0	100.5	103.5	103.5	105.0	105.0	105.5		
7	97.5	109.0	121.0	126.0	129.0	132.5	135.0	135.5	136.0		
8	97.0	96.0	96.0	96.5	97.5	98.0	99.0	99.5	99.5		
9	97.0	96.5	97.0	99.0	101.0	103.0	103.5	104.0	104.0		
10	97.5	97.0	97.5	99.0	101.0	102.0	103.0	103.5	103.5		
11	98.0	97.0	97.5	98.5	99.5	101.0	101.0	101.5	101.5		
							*				
A	92	84	82	80	79	75	72	71	70.5		
B	97	97	97	97	97	97	97	97	97		

VACUUM - 1×10^{-6}

* MOTOR AND ELECTRONICS STARTED AT THIS TIME

SEE RECORDED CHARTS FOR RESULTS

#1350A

APPENDIX B

VIBRATION DEVELOPMENTAL TESTS
(Goniometer and Compartment B)

Belock
Instrument Corporation

Environmental Testing Laboratory

College Point, New York

(UNCLASSIFIED)

REPORT OF VIBRATION TEST ON GONIOMETER ASSEMBLY COMPARTMENT B ELECTRONICS FOR PHILIPS ELECTRONIC INSTRUMENTS

TESTED BY	A. J. Arigone	E T L REPORT	1593-4
CHECKED BY	David Pykel	BELOCK S O	151-78
APPROVED BY	[illegible]	CUSTOMER PO	IN 24869XL
DATE	10 DECEMBER 1962		
GOVERNMENT INSPECTOR	NONE		

ADMINISTRATIVE DATA

DATE 10 December 1962

PURPOSE OF TEST: To determine the effects of Vibration on the physical and operational characteristics of the submitted units.

MANUFACTURER: PHILIPS ELECTRONIC INSTRUMENTS
750 South Fulton Avenue
Mount Vernon, New York

MANUFACTURER TYPE AND SERIAL NUMBER: Goniometer Assembly
Compartment B Electronics

DRAWINGS SPECIFICATIONS OR EXHIBIT: Tested in accordance with Customers Detailed Specifications

QUANTITY OF ITEMS TESTED: One (1) of each

EQUIPMENT: Unclassified

REPORT: Unclassified

DATE TEST COMPLETED: 19 November 1962

TEST CONDUCTED BY: ENVIRONMENTAL TESTING LABORATORY OF
BELOCK INSTRUMENT CORP.
112-03 14th Avenue
College Point 56, N.Y.

DISPOSITION OF SPECIMEN: Returned to client

ABSTRACT: It is the function of the Belock Environmental Laboratory, as an impartial testing agency in performing this test, to subject the specimen to vibration of magnitude and direction as specified in the detailed specification.

Belock

ETL 1593-4

S.O. 151-78

FACTUAL DATA

1. DESCRIPTION OF TEST APPARATUS:

1.1 Calidyne Shaker and Control System, Model No. 177A, Serial No. 15.
Last calibration date - 15 October 1962.

1.2 Calidyne Shaker and Control System, Model No. 161, Serial No. 15.
Last calibration date - 14 November 1962.

1.3 Endevco Accelerometer System, consisting of:
Accelerometer, Model No. 2212, Serial Nos. 2207, 2243 and Model No. 2213, Serial No. M818.
Amplifier, Model No. 2616, Serial No. CA13
Power Supply, Model No. 2622, Serial No. DA24
Last calibration date - 15 October 1962.

1.4 Ballantine True RMS VTVM, Model 320, Serial No. 4848.
Last calibration date - 30 October 1962.

1.5 Ballantine True RMS VTVM, Model 320, Serial No. 4847.
Last calibration date - 30 October 1962.

2. TEST PROCEDURE:

2.1 Goniometer Assembly:

The specimen was mounted in its normal mounting position to the test fixture and attached to the shaker table, Model No. 177A.
The specimen was vibrated for 10 minutes from 15 - 1500 cps, sweeping linearly at a maximum force of 20 g's. During the sweep the unit was observed for any resonant conditions.
The test unit was vibrated for 10 minutes along the thrust axis and 10 minutes in each of two orthogonal axes perpendicular to the thrust axis.

2.2 Compartment B Electronics:

The test procedure is the same as for the Goniometer Assembly except that shaker table Model No. 161 was used.

FACTUAL DATA (continued)

3. TEST RESULTS:

3.1 Goniometer Assembly:

a) Thrust Axis:

The following conditions were noted during the vibration test:

Frequency (cps)	Input (g's)	Output (g's) (top of side window counter)	Output (g's) (Goniometer casting motor end)
65	20	35	35
85	20	40	70
95	20	60	50
110	20	40	50
120	20	40	80
140	20	90	100
150	20	40	40
160	20	23	23
230-250	20	45	50
390	20	23	28
450	20	23	26
470	20	23	40
1000	20	23	50
1500	20	less than 20 g's	90

b) Major Horizontal Axis:

Testing discontinued at this time due to the fact that severe amplitudes were noted throughout the Goniometer structure, at 70 and 260 cps.

TEST RESULTS: (continued)

3.2 Compartment B Electronics

a) Major Horizontal Axis:

The following conditions were noted during vibration test:

Frequency (cps)	Input (g's)	Output (g's)
80	20	23
90	20	31
100	20	26
110	20	27
120	20	30
142	20	36
160	20	42
170	20	45
180	20	43
190	20	37
200-330	20	31-64
380	20	120
390	20	35
400	20	130
410	20	120
420	20	118
430	20	110
440	20	100
450	20	90
460	20	88
485	20	70
500	20	50
600	20	39
650-1500	less than 20 g's	

b) Minor Horizontal Axis:

Testing discontinued at this time, due to the fact that severe amplitudes were noted on the Compartment B Electronics Case, between 60 and 65 cps.

Belock Instrument Corporation

Environmental Testing Laboratory

College Point, New York

(UNCLASSIFIED)

REPORT OF VIBRATION TEST
ON
GONIOMETER ASSEMBLY
COMPARTMENT B ELECTRONICS
FOR
PHILIPS ELECTRONIC INSTRUMENTS

TESTED BY	[illegible]	E T L REPORT	1593-3
CHECKED BY	[illegible]	BELOCK SO	151-78
APPROVED BY	D K Stahl	CUSTOMER PO	IN 24869XL
DATE	7 DECEMBER 1962		
GOVERNMENT INSPECTOR	NONE		

(UNCLASSIFIED)

ADMINISTRATIVE DATA

DATE 7 December 1962

PURPOSE OF TEST: To determine the effects of Vibration on the physical and operational characteristics of the submitted units.

MANUFACTURER: PHILIPS ELECTRONIC INSTRUMENTS
750 South Fulton Avenue
Mount Vernon, New York

MANUFACTURER TYPE AND SERIAL NUMBER: Goniometer Assembly
Compartment B Electronics

DRAWINGS SPECIFICATIONS OR EXHIBIT: Tested in accordance with Customers Detailed Specifications.

QUANTITY OF ITEMS TESTED: One (1) of each

EQUIPMENT: Unclassified

REPORT: Unclassified

DATE TEST COMPLETED: 14 November 1962

TEST CONDUCTED BY: ENVIRONMENTAL TESTING LABORATORY OF
BELOCK INSTRUMENT CORP.
112-03 14th Avenue
College Point 56, N.Y.

DISPOSITION OF SPECIMEN: Returned to client

ABSTRACT: It is the function of the Belock Environmental Laboratory, as an impartial testing agency in performing this test, to subject the specimen to vibration of magnitude and direction as specified in the detailed specification.

Belock

ETL 1593-3

S.O. 151-78

FACTUAL DATA

1. DESCRIPTION OF TEST APPARATUS:

1.1 Calidyne Shaker and Control System, Model No. 177A, Serial No. 15.
Last calibration date - 15 October 1962.

1.2 Calidyne Shaker and Control System, Model No. 161, Serial No. 15.
Last calibration date - 14 November 1962.

1.3 Endevco Accelerometer System, consisting of:
Accelerometer, Model No. 2212, Serial Nos. 2207, 2243 and Model No. 2616, Serial No. CA13.
Power Supply, Model No. 2622, Serial No. CA24.
Last calibration date - 30 October 1962.

1.4 Ballantine True RMS VTVM, Model 320, Serial No. 4848.
Last calibration date - 30 October 1962.

1.5 Ballantine True RMS VTVM, Model 320, Serial No. 4847.
Last calibration date - 30 October 1962.

2. TEST PROCEDURE:

2.1 Goniometer Assembly:

The specimen was mounted in its normal mounting position to the test fixture and attached to the shaker table, Model No. 177A.
The specimen was vibrated for 10 minutes from 15 - 1500 cps, sweeping linearly at a maximum force of 20 g's. During the sweep the unit was observed for any resonant conditions.
The test unit was vibrated for 10 minutes along the thrust axis and 10 minutes in each of two orthogonal axes perpendicular to the thrust axis.

2.2 Compartment B Electronics:

The test procedure is the same as for the Goniometer Assembly except that shaker table Model No. 161 was used.

FACTUAL DATA (continued)

3. TEST RESULTS:

3.1 Goniometer Assembly:

The following conditions were noted during vibration test:

Frequency (cps)	Input (g's)	Output (g's) (Detector Mount)	Output (g's) (Motor Balance)
75	20	30	30
85	20	35	30
90	20	40	40
100	20	60	50 *

* Aluminum shear pin on worm gear sheared at this time, testing discontinued.

3.2 Compartment "B" Electronics:

The following conditions were noted during vibration test:

a) Thrust Axis:

Frequency (cps)	Input (g's)	Output (g's)
90	20	21
100	20	22
110	20	22
120	20	23
130	20	24
150	20	25
160	20	26
180	20	27
190	20	29
200	20	31
220	20	32
240	20	40
260	20	60
280	20	65
300	20	60
330	20	85
340	20	85
350	20	95
360	20	90
380	20	110
400	20	130
420	20	145

FACTUAL DATA

TEST RESULTS:

Compartment "B" Electronics:

Thrust Axis (continued)

Frequency (cps)	Input (g's)	Output (g's)
440	20	60
460	20	50
480	20	40
490	20	55
525	20	40
550	20	60
600	20	40
700 to 1500	20	Less than 20

b) **Minor Horizontal:**

Frequency (cps)	Input (g's)	Output (g's)
60	20	22.5
70	20	24
80	20	25
100	20	40
115	20	50 to 100
120	20	55
140	20	26
160	20	22
260	20	24
350	20	24
360 to 1500	20	Less than 20

Mounting flange sheared during vibration in this plane. Testing discontinued at this time.

APPENDIX C

RANDOM VIBRATION DEVELOPMENTAL TESTS
(Diffractometer Head and Compartment B)

Test Report No. H40-3613

No. of Pages 6

Report of Test on

X-RAY DIFFRACTOMETER ASSEMBLY

VIBRATION TEST

for

PHILIPS SPACE DEVELOPMENT

Associated Testing Laboratories, Inc.

Wayne, New Jersey

Date January 21, 1963

	Prepared	Checked	Approved
By	W. Kes	R. Hassett	D. Jorgensen
Signed	W. Kes	R. Hassett	D Jorgensen
Date	1-21-63	1-21-63	1-21-63

Administrative Data

1.0 Purpose of Test:

To subject the submitted X-ray Diffractometer Assembly to a Vibration Test in accordance with the Test Procedure of this report.

2.0 Manufacturer: Philips Space Development
900 South Columbus Avenue
Mt. Vernon, New York

3.0 Manufacturer's Type or Model No.: Serial Number 3D, Units 1 and 2

4.0 Drawing, Specification or Exhibit: Paragraph No. 31513 of Hughes Aircraft Corporation Specification No. 224810, Revision C and verbal instructions from an Engineering Representative of Philips Space Development.

5.0 Quantity of Items Tested: One Assembly consisting of an X-ray Diffractometer Head (Unit 1) and a Compartment B Electronics Package (Unit 2)

6.0 Security Classification of Items: Unclassified

7.0 Date Test Completed: January 12, 1963

8.0 Test Conducted By: **Associated Testing Laboratories, Inc.**

9.0 Disposition of Specimens: Returned to Philips Space Development

10.0 Abstract:

The submitted X-ray Diffractometer Assembly was subjected to a Vibration Test in accordance with the referenced specification. The following physical damage was observed to the two units of the Assembly as a result of the test:

10.0 Abstract: (Continued)

X-ray Diffractometer Head

During the first sweep in the Y Axis of vibration, the connector cable broke. During the fifth sweep in the Y Axis of vibration, a screw from the cover loosened and fell out. During the last sweep in the Z Axis of vibration, the metal strip covering the 2-pin connector tore where the pins protruded and the metal shield covering the printed circuit board broke off.

Compartment B Electronics Package

At the completion of the Y Axis of vibration, the black cover was noted to be loose.

LIST OF APPARATUS

1. Vibration System, Ling Electronics Corporation, consisting of the following:

    a. Vibration Exciter, Model A246
    b. Power Cubicle, Model PP-20/24
    c. Remote Control Console, Model R-1001.

2. Random Noise Control Console, Ling Electronics Corporation, Model R-1001-3.

3. Random Noise Generator, General Radio Company, Model 1390B.

4. Variable Frequency Bandpass Filter, Krohn-Hite, Model 330-M.

5. True RMS AC Voltmeter, Ballantine Laboratories, Model 330S/2.

6. Accelerometer, Endevco Corporation, Model 2215C.

TEST PROCEDURE

The Vibration Test was conducted in accordance with Paragraph 3.3.3 of Hughes Aircraft Corporation Specification Number 224810, Revision C and verbal instructions from an Engineering Representative of Philips Space Development. However, for completeness of this report, the following is the Test Procedure as it was conducted.

The X-ray Diffractometer Assembly consisted of two individual components, an X-ray Diffractometer Head and a Compartment B Electronics Package. The units were subjected to a combined random frequency and sinusoidal frequency Vibration Test along each of the three mutually perpendicular axes identified in Figure 1. The same test fixture was used to mount both units to the Vibration Machine. The X-ray Diffractometer Head was mounted to the test fixture in accordance with Philips Space Development Drawing Number R6-2062-1, Revision D. The Compartment B Electronics Package was mounted to the test fixture in accordance with Philips Space Development Drawing Number B-101742, Revision E.

Each unit was individually subjected to simultaneous random frequency and sinusoidal frequency vibration over the frequency range of 5 to 1500 cps. The sinusoidal frequency vibration levels in the thrust axis were 0.5" da or ±18 g, whichever was the limiting factor. The sinusoidal frequency vibration levels in the lateral axes were 0.5" da or ±16 g, whichever was the limiting factor. The sinusoidal frequency range of 5 to 1500 cps was traversed in a two minute period. A total of six frequency sweeps were conducted in each of the three mutually perpendicular axes.

During the first sinusoidal frequency sweep in each axis of vibration, the random frequency vibration level was maintained at .015 g^2/cps over the frequency range of 100 cps to 1500 cps. During the following 5 sweeps in each axis of vibration, the random frequency vibration level was maintained at .003 g^2/cps.

A crystal accelerometer was attached to the test fixture and was used to measure the applied vibration levels. Initially, the test fixture and a dummy load were equalized for the required random frequency vibration levels. All subsequent equalizations were performed with the actual test units mounted to the test fixture. The random frequency vibration levels were determined and monitored on a system which contains thirty-nine parallel bandpass

TEST PROCEDURE

(Continued)

filters with individual attenuators for spectrum shaping. Each filter has a bandwidth of 50 cps. The system also contains forty-two monitoring circuits with level meters which read directly in g^2/cps. The sinusoidal frequency vibration levels were calibrated in millivolts on an AC Voltmeter. During the actual sweeps, the sinusoidal frequency vibration levels were manually controlled.

The units were subjected to the Vibration Test for a period of twelve minutes in each axis of vibration. At the completion of each sinusoidal frequency sweep, the units were examined for any evidence of physical damage.

TEST DATA AND OBSERVATIONS

Unit	Axis of Vibration	Observations
X-ray Diffractometer Head	X (lateral)	No physical damage
Compartment B Electronics Package	X (lateral)	No physical damage
X-ray Diffractometer Head	Y (thrust)	On the first sweep, the connector cable broke. On the fifth sweep, a screw from the cover loosened and fell out.
Compartment B Electronics Package	Y (thrust)	At the completion of this axis of vibration, the black cover was noted to be loose.
Compartment B Electronics Package	Z (lateral)	No physical damage
X-ray Diffractometer Head	Z (lateral)	During the last sweep, the metal strip covering the 2-pin connector tore where the pins protruded, and the metal shield covering the printed circuit board broke off.

TEST RESULTS

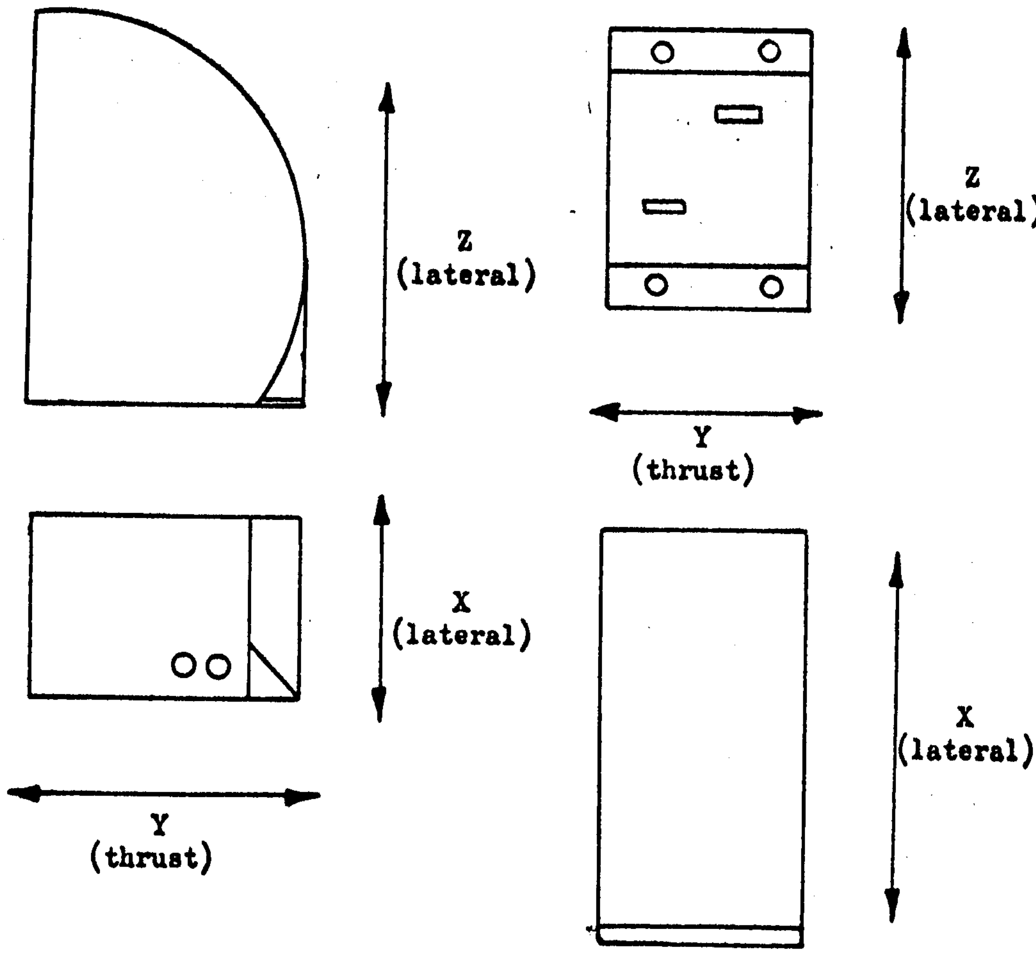
The following physical damage was observed to the two units of the X-ray Diffractometer Assembly as a result of the Vibration Test.

X-ray Diffractometer Head

During the first sweep in the Y Axis of vibration, the connector cable broke. During the fifth sweep in the Y Axis of vibration, a screw from the cover loosened and fell out. During the last sweep in the Z Axis of vibration, the metal strip covering the 2-pin connector tore where the pins protruded and the metal shield covering the printed circuit board broke off.

Compartment B Electronics Package

At the completion of the Y Axis of vibration, the black cover was noted to be loose.



X-ray Diffractometer Head

Compartment B
Electronics Package

Figure 1

Identification of Axes of Vibration

APPENDIX D

ACCEPTANCE TEST PROCEDURE
(Model P-4/P-5 Diffractometer)

App	Rev	Date
J.L.	A	12-30-63

T E S T

S P E C I F I C A T I O N

Model P4 X-Ray Diffractometer

Issued by: J. Lebid Date: 12-26-63

Approved by: E. Blaustein Date: 12-30-63

Approved by: E. Meisner Date: 12-30-63

1. SCOPE

This specification establishes the Functional Test Procedure for Model P4 Surveyor X-Ray Diffractometer.

2. APPLICABLE DOCUMENTS

The following specification forms a part of this document:

Jet Propulsion Laboratory

30846D Design Specification Surveyor Prototype Equipment Scientific X-Ray Diffractometer.

3. TEST EQUIPMENT

3.1 System Control Test Panel

3.2 Interconnecting Cable Assembly, Philips

3.3 Electronic Counter, Hewlett-Packard, Model 524B

3.4 Test Panel/Counter Adapter

3.5 Oscilloscope, Tektronix, Models 535, 531A, or 541, with Type Type M plug-in unit

3.6 Standard Norelco Circuit Panel, Type 12095/6

3.7 Powdered Quartz Sample, 400 Mesh

4. PREPARATION FOR TEST

4.1 Place all switches in the OFF position.

4.2 Connect the diffractometer and the test equipment as shown Figure 1.

4.3 An asterisk (*) preceding a paragraph indicates data is to be taken and/or recorded.

5. GONIOMETER SPEED TEST

5.1 Connect ✱ MKR IN test point of System Control Test Panel (angular mark output) to the SIGNAL INPUT of the electronic counter. Set FUNCTION SELECTOR of the counter to PERIOD and set TIME UNIT to milliseconds. Set DISPLAY TIME to INF, so that count will be displayed until the Reset Button is pressed.

Note: Since the PERIOD input circuit of the counter is designed to trigger at the zero-volt crossing of a negative going voltage, an adapter is necessary between the Signal Control Test Panel and the counter. The purpose of the adapter is to make the counter trigger at the leading edge of the pulse.

The counter will start counting in milliseconds when an angular mark pulse comes in and will stop automatically at the next marking pulse. If the reset button is pressed before the next pulse, the counter will automatically start counting again at this third pulse.

* 5.2 With the goniometer in the home position (7°) start the motor by actuating the FORWARD command switch on the System Control Test Panel. Reset counter and measure elapsed time between:

8° - 9°	17° - 18°
10° - 11°	19° - 20°
13° - 14°	22° - 23°
15° - 16°	24° - 25°

The measured intervals shall not differ more than ±1% from the average. Enter data in Table 1. The time interval shall be 120 ±12 seconds.

* 5.3 Press FAST FORWARD switch and measure time periods between:

28° - 29°		37° - 38°	
30° - 31°		39° - 40°	
33° - 34°		42° - 43°	
35° - 36°		44° - 45°	

The measured time intervals shall not differ more than ±1% from the average. Enter data in Table 1. The time interval shall be 15 ±10% seconds.

* 5.4 Actuate FORWARD command switch between 50th and 51st marker signal. Measure intervals between:

52° - 53°	61° - 62°
54° - 55°	63° - 64°
57° - 58°	66° - 67°
59° - 60°	68° - 69°

Same requirements as in 5.2. Enter data in Table 1.

* 5.5 Actuate FAST FORWARD command switch between 69th and 70th marker signal. Measure interval between:

73° - 74°	82° - 83°
75° - 76°	84° - 85°
78° - 79°	87° - 88°
80° - 81°	

Same requirements as in 5.3. Enter data in Table 1.

* 5.6 Actuate FAST REVERSE switch and measure interval between 90° and 80° and between 30° and 20°. This can be done by setting the Function Selector of the counter to: "10 - PERIOD AVERAGE". The time interval for 10° shall be 75 ±10% seconds. Enter data in Table 1.

5.7 Return goniometer to its home position.

6. <u>OPERATING TESTS</u>

6.1 Insert powdered quartz sample in the sample holder. Connect CH.1 OUT on System Control Test Panel to SIGNAL INPUT NEGATIVE of the Circuit Panel rate meter. Connect marker signal pen of the Circuit Panel recorder to RECORDER SOLENOID on System Control Test Panel.

6.2 Start Norelco Circuit Panel and actuate POWER ON and HIGH VOLTAGE ON switches on System Control Test Panel.

6.3 With the goniometer in the home position, actuate FORWARD command switch on System Control Test Panel.

* 6.4 Make recordogram for the complete angular range from 7° to 90°. Attach charts to data sheets.

6.5 Return goniometer to zero position.

* 6.6 The recordogram, mentioned in Paragraph 6.4, will show the diffraction peak from the 1.01 plane of the quartz sample. Determine the following and enter data in Table 2:

a) Peak width at 1/2 height shall be 0.22° or less (20°)

b) Peak width at 1/10 height shall be 0.45° or less

c) Peak intensity shall be 2300cps or greater

d) Peak - background/background shall be 27 or greater

e) Center of gravity of peak 26.65° ±0.05° (2θ)

f) Symmetry (see Figure 1 of JPL Spec. #30846D) A/B = 1.12

7. REPRODUCIBILITY

* 7.1 Record the 1.01 peak 10 times by scanning from 25° to 27°, using the FORWARD speed. Determine the location of the peak in each recordogram; the criterion for the location is the center of the line that connects the two 1/2 heights of the peak. The reproducibility shall be better than 0.05°. Enter data in Table 3 and attach charts to data sheet.

* 7.2 With the motor in the FORWARD speed, scan over the 1.01 peak again, and stop the goniometer at the top of the peak. Connect Channel 1 to the electronic counter and determine the peak intensity 10 times. Accumulate at least 100,000 counts every time. The reproducibility shall be ±3% or better. Enter data in Table 3.

* 7.3 Record the 1.21 peak of quartz 10 times by scanning from 59° to 61°, using the FORWARD speed. The reproducibility of the location of the peak, as defined in Paragraph 7.1, shall be better than 0.05°. Enter data in Table 3 and attach charts to data sheets.

8. MEASUREMENT OF VIDEO CHANNEL OUTPUT CHARACTERISTICS

8.1 Connect oscilloscope to the video output (MX IN test point on System Control Test Panel).

* 8.2 Determine voltage range of pulses. Voltage range shall be 0 to +5 ±1 volts. Enter data in Table 4.

* 8.3 Determine rise time of pulse. Rise time shall be 50μ seconds maximum. Enter data in Table 4.

* 8.4 Determine fall time of pulse. Fall time shall be 50μ seconds maximum. Enter data in Table 4.

9. <u>MEASUREMENT OF ANGULAR MARKER CHANNEL OUTPUT CHARACTERISTICS</u>

9.1 Connect oscilloscope to ⚹ MARKER test point on System Control Test Panel.

* 9.2 Determine the pulse characteristics with the goniometer at the home position (7°). The angular marker signal shall be a continuous square wave signal, 40cps ±10%, 0-5 ±1 volts. Enter data in Table 5.

* 9.3 With the goniometer in the 90° position, measure the marker signal pulses. There shall be a continuous square wave signal, symmetrical, 0-5 ±1 volts, 80cps ±10%. Enter data in Table 5.

* 9.4 Measure the characteristics of an angular marker signal anywhere between (but not at) the 7th degree and 90th degree. Enter data in Table 5.

* 9.5 Photograph the signal as it appears on the oscilloscope. The signal shall be as follows:

a) Voltage level: 0-5 ±1 volts

b) Pulse length: 200 milliseconds

c) Rise time: 5 milliseconds maximum

d) Fall time: 5 milliseconds maximum

10. PDSL TEST INFORMATION SHEET

* 10.1 Fill out and complete the Test Information Sheet.

PDSL TEST INFORMATION SHEET

1. Description of Test ____

____

2. Instrument ______________________ 8. Date ______________________

3. Subassembly ______________________ 9. Start Time ______________________

4. Test No. ___ In a series of ________ 10. Stop Time ______________________

5. Test Engineer ______________________ 11. Temperature __________ °C.

6. Technicians 1. ______________________ 12. Barometric Pressure ____ mm Hg

2. ______________________

3. ______________________

7. Observer ______________________ Quality Assurance ______________

Name Company

13. Test Equipment Used

Name	Make	Model	Serial #	Calibration Date

14. Problems Encountered and Comments: ______________________

____

____

____

15. Approved:

Test Engineer ______________________ Date ______________

Observer ______________________ Date ______________

Name Company

Quality Assurance ______________________ Date ______________

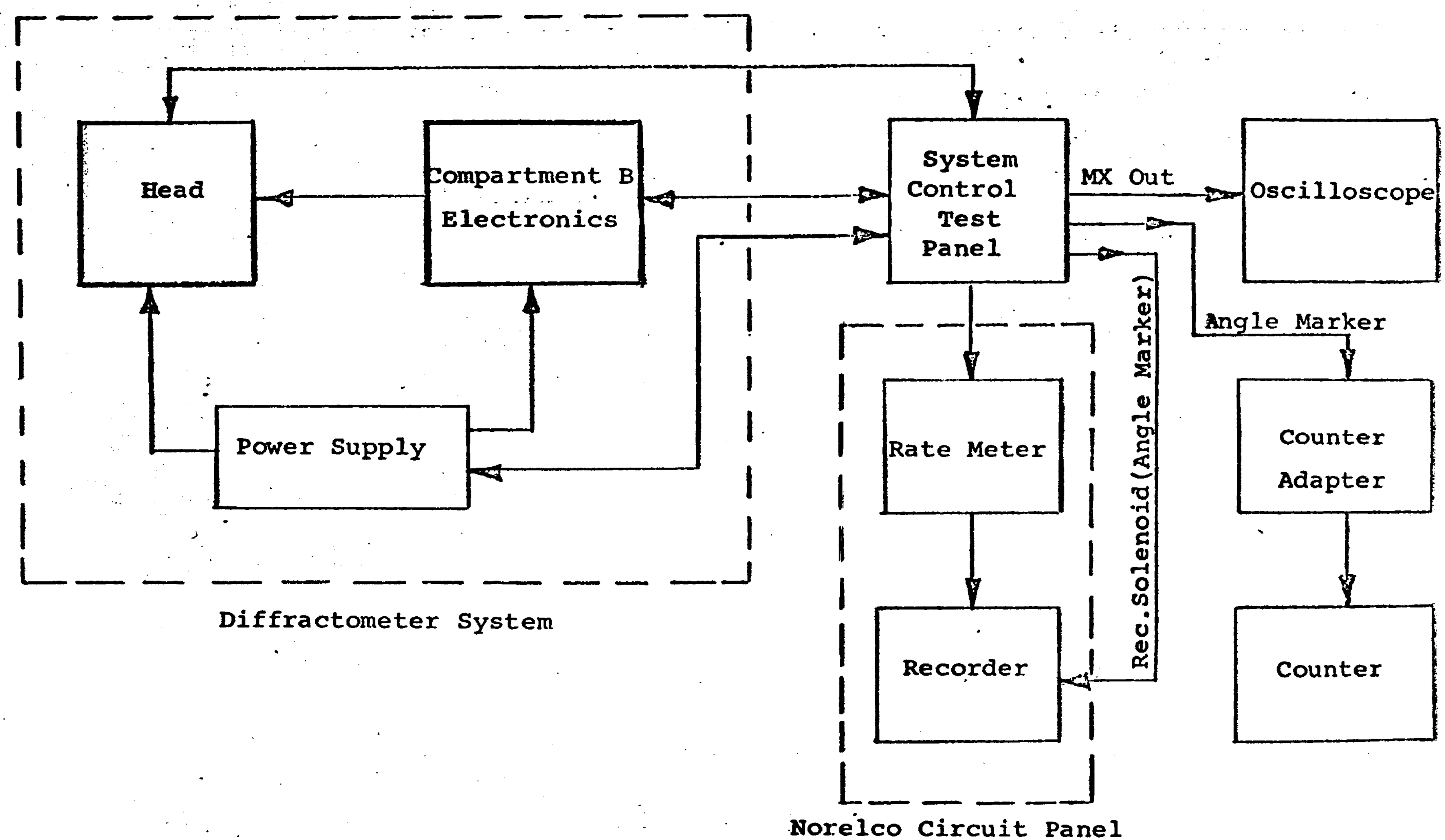


Figure 1: Diffractometer Test Setup

APPENDIX E

ACCEPTANCE TEST DATA

(Model P-4 Diffractometer)

DATA SHEET

Table 1: GONIOMETER SPEED TEST

(Para. 5.2)

Scanning (degrees) from	to	Time Interval (seconds)	Deviation From Average (seconds)	Difference From Average (%)
8	9			
10	11	120.[illegible]	-.082	-.068
13	14	120.583	+.094	+.078
15	16	120.405	-.084	-.069
17	18	120.053	-.436	-.36
19	20	121.176	+.637	+.53
22	23	120.[illegible]	-.066	-.055
24	25	120.427	-.062	-.052

Total 843.424

Average 120.489

Intervals shall be ≤ ±1% of Average.
Intervals shall = 120 ±12 sec.

(Para. 5.3)

Scanning (degrees) from	to	Time Interval (seconds)	Deviation From Average (seconds)	Difference From Average (%)
28	29	15.139	+.081	+.52
30	31	15.078	+.020	+.13
33	34	14.988	-.070	-.47
35	36	14.987	-.071	-.47
37	38	15.162	+.104	+.69
39	40	15.001	-.057	-.36
42	43	14.955	-.103	-.68
44	45	15.133	+.075	+.48

Total 120.463

Average 15.058

Intervals shall be ≤ ±1% of Average.
Intervals shall = 15 ±1.5 sec.

Table 1: GONIOMETER SPEED TEST (Cont'd)

(Para. 5.4)

Scanning (degrees) from	to	Time Interval (seconds)	Deviation From Average (seconds)	Difference From Average (%)
52	53	121.184	+.699	+0.58
54	55	120.449	-.036	+0.03
57	58	120.666	+.181	+0.15
59	60	119.4[illegible]	-1.057	-0.88
61	62	121.322	+.837	+0.69
63	64	120.490	+.005	+0.004
66	67	119.6[illegible]	-.129	-0.11
68	69	120.511	+.026	+.02

0000

Total 963.664

Average 120.485

Intervals shall be ≦ ±1% of Average.
Intervals shall = 120 ±12 sec.

(Para. 5.5)

Scanning (degrees) from	to	Time Interval (seconds)	Deviation From Average (seconds)	Difference From Average (%)
73	74	15.150	+.071	+0.47
75	76	14.92[illegible]	-.155	+1.03
78	79	15.160	+.081	+0.54
80	81	15.117	+.038	+0.25
82	83	15.011	-.068	-0.45
84	85	15.163	+.084	+0.56
87	88	15.02[illegible]	-.061	-0.31

Total 105.553

Average 15.079

Intervals shall be ≦ ±1% of Average.
Intervals shall = 15 ±1.5 sec.

(Para. 5.6)

Scanning (degrees) from	to	Time Interval (seconds)
90	80	75.361
30	20	75.310

Intervals shall = 75 ±7.5 sec.

Table 2: OPERATIONAL DATA

(Para. 6.6)

		Measured Value	Required Value	* 2
1.	Peak width at 1/2 height	$\frac{13.9}{79.8} = .17\frac{1}{2}°$	≦ 0.22°	$\frac{13.8}{80.0} = .17\frac{1}{4}°$
2.	Peak width at 1/10 height	$\frac{27.0}{79.8} = .34°$	≦ 0.45°	$\frac{26.7}{80.0} = .33\frac{1}{2}°$
3.	Peak intensity	3100 cps.	≧ 2300cps	
4.	Peak-background/background	136	≧ 27	
5.	Center of gravity of peak	qtz standard	26.65 ±0.05°	
6.	Symmetry $\frac{A}{B}$ =	$\frac{14.0}{13.0} = 1.07\frac{1}{2}$	1.12	$\frac{13.8}{12.9} = 1.07\frac{1}{2}$

backround: $\frac{800}{35.1 \text{(ave 4)}} = 22.8$ cps

Table 3: REPRODUCIBILITY

(Para. 7.1)

Location of 1.01 peak (25°-27°):

		Dev.	
1)*	26.823	0.020	Max
2)	26.836	0.007	
3)	26.840	0.003	
4)	26.843	0.000	
5)	26.843	0.000	
6)	26.840	0.003	
7)	26.843	0.000	
8)	26.843	0.000	
9)	26.843	0.000	
10)	26.843	0.000	

ave ~ 26.840

Reproducibility shall be ≦ 0.05°

(Para. 7.3)

Location of 1.21 peak (59°-61°):

1)	60.080	Max Dev < 0.036 [1]
2)	60.090	[1] Accuracy ≤ .016
3)	60.090	
4)	60.086	
5)	60.086	
6)	60.103	
7)	60.073	
8)	60.066	
9)	60.083	
10)	60.083	

Reproducibility shall be ≦ 0.05°

* 1) run ~ 2 min after recorder turnon. Accuracy 0.003°

(Para. 7.2)

Location of 1.01 Quartz peak: 26.84

Counts/sec. for 1.01 Quartz peak:

	Time (sec.) for 128,000 counts	c.p.s.
1)	41.9	3060
2)	41.6	3080
3)	41.4	3090
4)	41.0	3120
5)	41.0	3120
6)	41.0	3120
7)	41.2	3100
8)	41.1	3100
9)	41.0	3120
10)	41.2	3100

Average 3100 cps. Max Dev = 2.2%

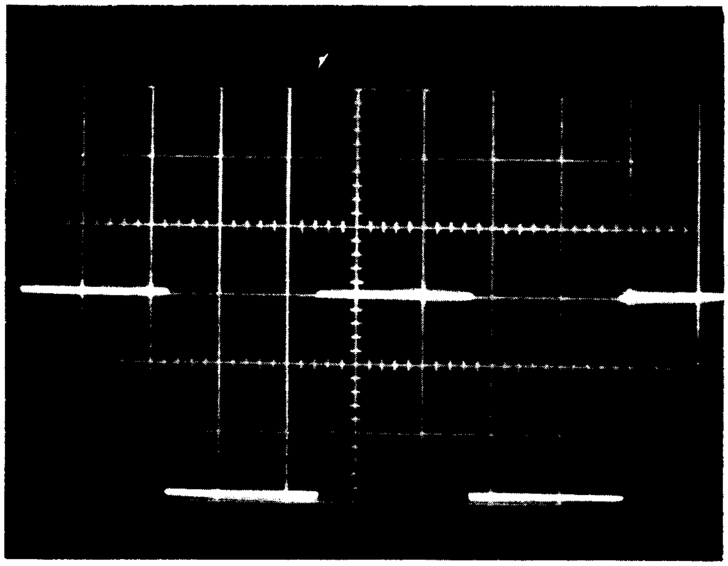
Reproducibility shall be ≦ ±3%

Table 4: CHARACTERISTICS OF VIDEO OUTPUT

		Measured Value	Required Value
(Para. 8.2)	Pulse voltage range	+5.2 v pp	0-5 ±1 volts
(Para. 8.3)	Rise time	20μ sec.	50μsec max
(Para. 8.4)	Fall time	2μ sec	50μsec max

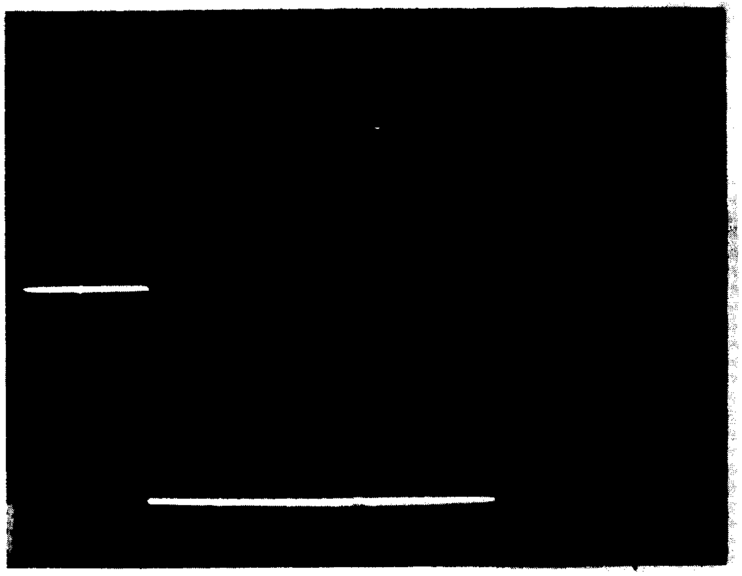
Table 5: CHARACTERISTICS OF ANGULAR MARKER OUTPUT

		Measured Value	Required Value
(Para. 9.2)	Marker signal pulse at home pos. (7°)		
	Voltage Range	+5.2V pp.	0-5 ±1 volts
	Frequency	44.8cps	45 ±4cps
(Para. 9.3)	Marker signal pulse at 90°		
	Voltage Range	+5.2 v pp	0-5 ±1 volts
	Frequency	89.3cps	90 ±8cps
(Para. 9.4)	Voltage level	+5.2v pp	0-5 ±1 volts
	Pulse length	195 m.sec	200msec
	Rise time	20μ sec	5msec max
	Fall time	2μ sec.	5msec max



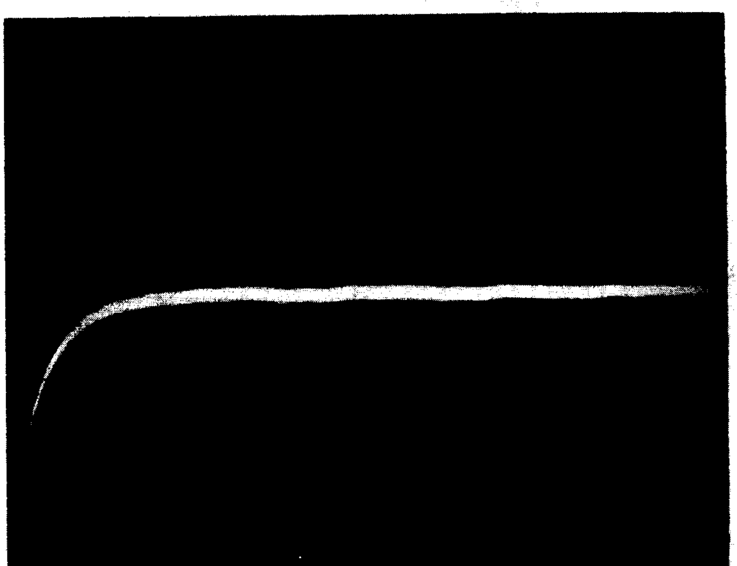
P4

HOME & MKR. OUTPUT
5MSEC/CM
2V/CM
46 CPS FROM H.P. COUNTER



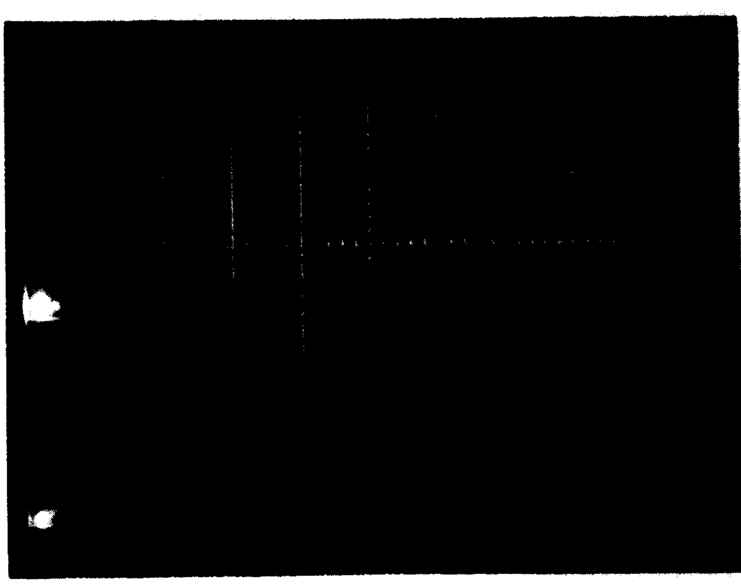
P4

∡ MKR. PULSE WIDTH
2V/CM
0.1 SEC/CM.



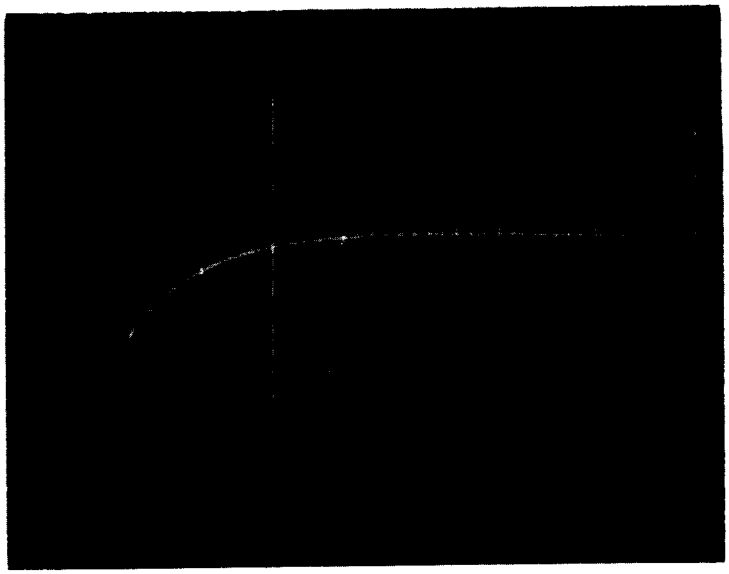
P4

∡ MKR RISE TIME
2 μSEC/CM



P4

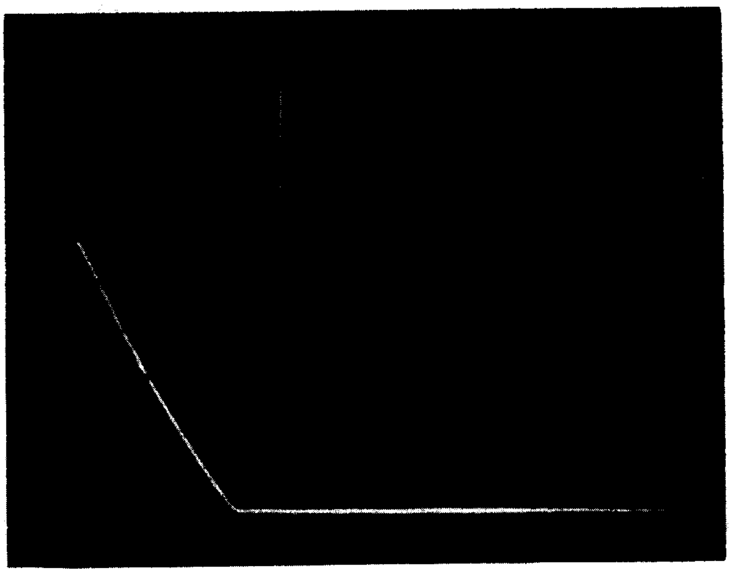
∡ MKR. FALL TIME
0.2 μSEC/CM



P4

VIDEO RISE TIME

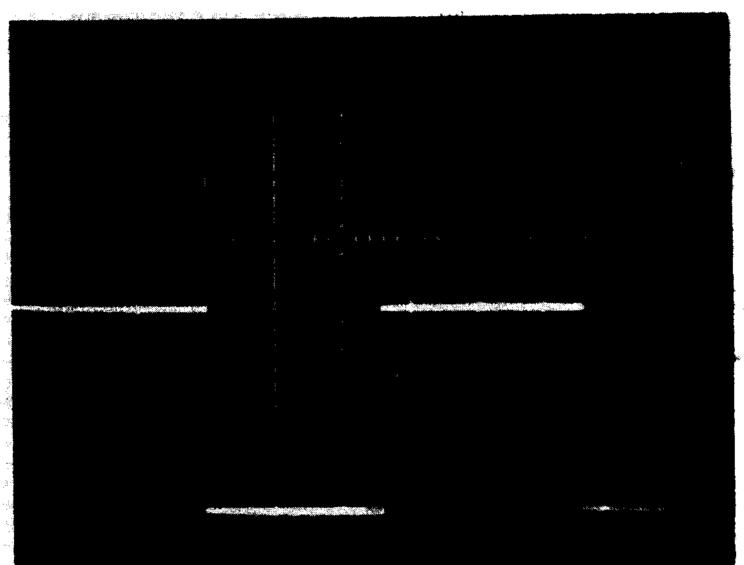
10 µSEC/CM



P4

VIDEO FALL TIME

1 µSEC/cm



P4

REVERSE ∓ MKR. OUTPUT

2V/CM

2 M/SEC/CM

90 CPS FROM H.P. COUNTER

APPENDIX F

ACCEPTANCE TEST DATA

(Model P-5 Diffractometer)

Table 1: GONIOMETER SPEED TEST

(Para. 5.2)

Scanning (degrees) from – to	Time Interval (seconds)	Deviation From Average (seconds)	Difference From Average (%)
8 – 9	121.561	+.346	+0.29
10 – 11	120.[illegible]99	-.366	-0.30
13 – 14	121.[illegible]6	+.691	+0.57
15 – 16	120.834	-.381	-0.31
17 – 18	121.732	+.517	+0.43
19 – 20	120.656	-.559	-0.46
22 – 23	120.654	-.561	-0.46
24 – 25	121.537	+.322	+0.27

Total 969723

Average 121.215

Intervals shall be ≤ ±1% of Average.
Intervals shall = 120 ±12 sec.

(Para. 5.3)

Scanning (degrees) from – to	Time Interval (seconds)	Deviation From Average (seconds)	Difference From Average (%)
28 – 29	15.181	+.038	+0.25
30 – 31	15.099	-.044	-0.29
33 – 34	15.206 57	+.063	+0.42
35 – 36	15.084 8	-.059	-0.39
37 – 38	15.220	+.077	+0.51
39 – 40	15.079	-.064	-0.42
42 – 43	15.091	-.052	-0.34
44 – 45	15.186	+.043	+0.27

Total 121.146

Average 15.143

Intervals shall be ≤ ±1% of Average.
Intervals shall = 15 ±1.5 sec.

Table 1: GONIOMETER SPEED TEST (Cont'd)

(Para. 5.4)

Scanning (degrees) from – to	Time Interval (seconds)	Deviation From Average (seconds)	Difference From Average (%)
52 – 53	121.530	+0.408	+0.34
54 – 55	120.641	-0.481	-0.40
57 – 58	121.884	+0.762	+0.63
59 – 60	120.623	-0.499	-0.41
61 – 62	121.706	+0.584	+0.48
63 – 64	120.622	-0.500	-0.41
66 – 67	120.628	-0.494	-0.41
68 – 69	121.341	+0.219	+0.18

Total 968.975

Average 121.122

Intervals shall be ≤ ±1% of Average.
Intervals shall = 120 ±12 sec.

(Para. 5.5)

Scanning (degrees) from – to	Time Interval (seconds)	Deviation From Average (seconds)	Difference From Average (%)
73 – 74	15.213	+0.085	+0.56
75 – 76	15.069	-0.059	-0.39
78 – 79	15.093	-0.035	-0.23
80 – 81	15.181	+0.063	+0.42
82 – 83	15.094	-0.054	-0.36
84 – 85	15.080	-0.048	-0.32
87 – 88	15.188	+0.060	+0.40

Total 105.898

Average 15.128

Intervals shall be ≤ ±1% of Average.
Intervals shall = 15 ±1.5 sec.

(Para. 5.6)

90 – 80	75.73
30 – 20	75.52

Intervals shall = 75 ±7.5 sec.

Table 2: OPERATIONAL DATA

(Para. 6.6)

		Measured Value	Required Value	
1.	Peak width at 1/2 height	$\frac{14.2}{80.4} = .17\frac{3}{4}°$	≦ 0.22°	$\frac{14.4}{80.2} = .18°$
2.	Peak width at 1/10 height	$\frac{27.0}{80.4} = .33\frac{1}{2}°$	≦ 0.45°	$\frac{27.8}{80.4} = .33\frac{1}{2}°$
3.	Peak intensity	3830	≧ 2300cps	
4.	Peak-background/background	103	≧ 27	
5.	Center of gravity of peak	qtz standard	26.65 ±0.05°	
6.	Symmetry $\frac{A}{B}$ =	$\frac{14.0}{13.0} = 1.07\frac{1}{2}$	1.12	$\frac{14.1}{13.6} = 1.03\frac{1}{2}$

bacKround $\frac{800}{21.8 (\text{ave})} \approx 37$

Table 3: REPRODUCIBILITY

(Para. 7.1)

Location of 1.01 peak: (25°-27°):

1) 26.494 Max.Dev. = 0.008 ≃ 0.01°
2) 26.493
3) 26.495
4) 26.496
5) 26.498
6) 26.499
7) 26.498
8) 26.500
9) 26.494
10) 26.501

Reproducibility shall be ≦ 0.05°

ave ≃ 26.497. Dev = $^{+0.003}_{-0.003}$ (nearest 0.002)

(Para. 7.3)

Location of 1.21 peak (59°-61°):

1) 59.844 Max Dev = 0.01°
2) 59.850
3) 59.850
4) 59.853
5) 59.853
6) 59.848
7) 59.845
8) 59.845
9) 59.842
10) 59.846

Reproducibility shall be ≦ 0.05°

(Para. 7.2)

Location of 1.01 Quartz peak: 26.50

Counts/sec. for 1.01 Quartz peak:

	time for 128,000 counts (sec)	counts/sec
1)	33.2	3860
2)	33.6	3810
3)	33.2	38500
4)	33.3	3850
5)	33.3	3850
6)	33.6	3810
7)	33.5	3820
8)	33.6	3810
9)	33.5	3820
10)	33.5	3820
Average	~ 3830	

Max Dev = 0.12%

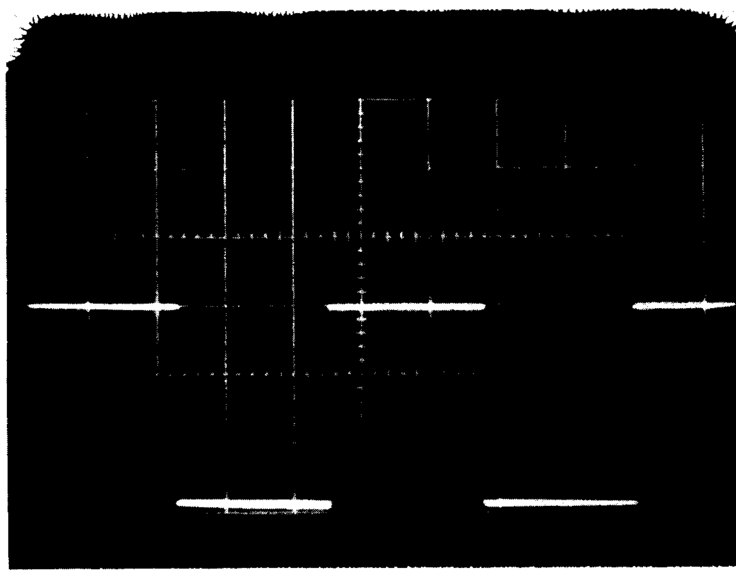
Reproducibility shall be ≦ ±3%

Table 4: CHARACTERISTICS OF VIDEO OUTPUT

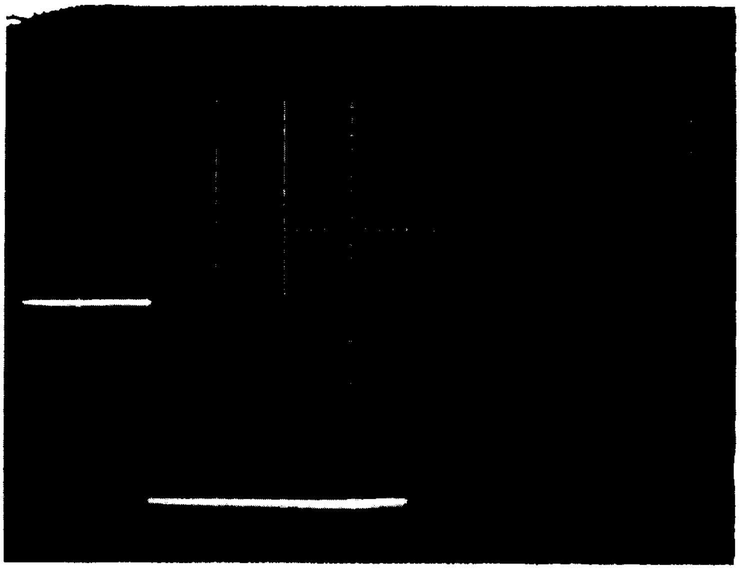
		Measured Value	Required Value
(Para. 8.2)	Pulse voltage range	+5.2V. P-P	0-5 ±1 volts
(Para. 8.3)	Rise time	20µSec	50µsec max
(Para. 8.4)	Fall time	2µSec	50µsec max

Table 5: CHARACTERISTICS OF ANGULAR MARKER OUTPUT

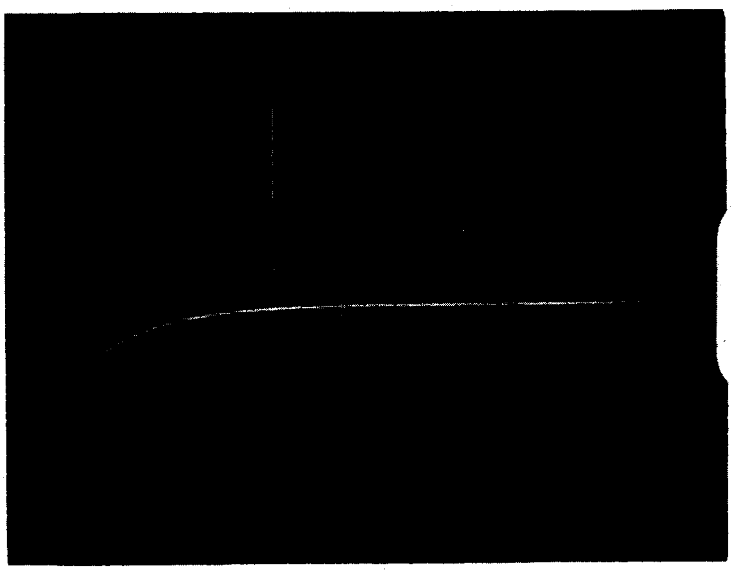
		Measured Value	Required Value
(Para. 9.2)	Marker signal pulse at home pos. (7°)		
	Voltage Range	+5.2V. P-P.	0-5 ±1 volts
	Frequency	44.8 cps	45 ±4cps
(Para. 9.3)	Marker signal pulse at 90°		
	Voltage Range	+5.2V. P-P	0-5 ±1 volts
	Frequency	89.3cps	90 ±8cps
(Para. 9.4)	Voltage level	+5.2V. P-P	0-5 ±1 volts
	Pulse length	195msec.	200msec
	Rise time	20µsec	5msec max
	Fall time	2µSec	5msec max



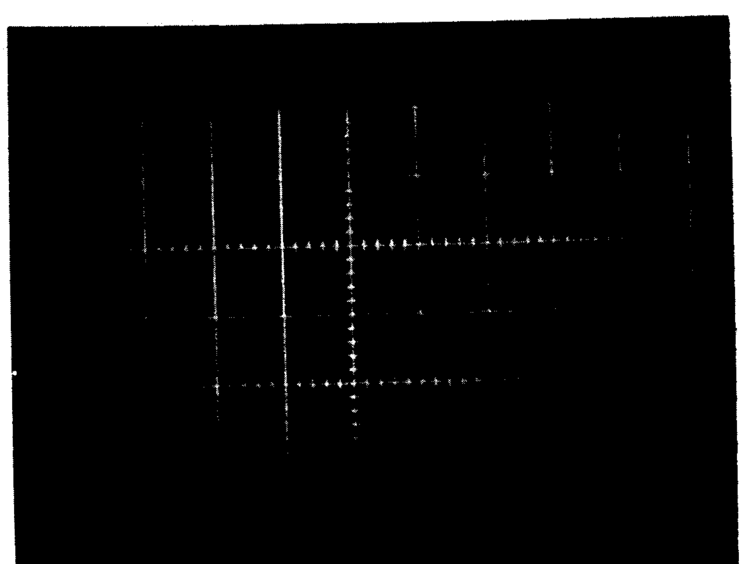
P5
HOME $\not\!\! Z$ MKR OUTPUT
5MSEC/CM
2V/CM
44.7 CPS FROM H.P. COUNTER



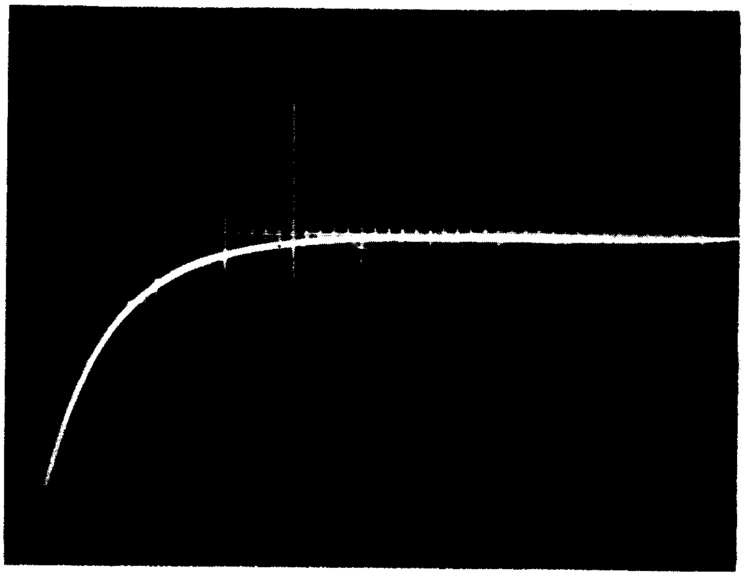
P5
∡ MKR PULSE WIDTH
2V/CM
0.1 SEC/CM



P5
∡ MKR RISE TIME
2 μSEC/CM



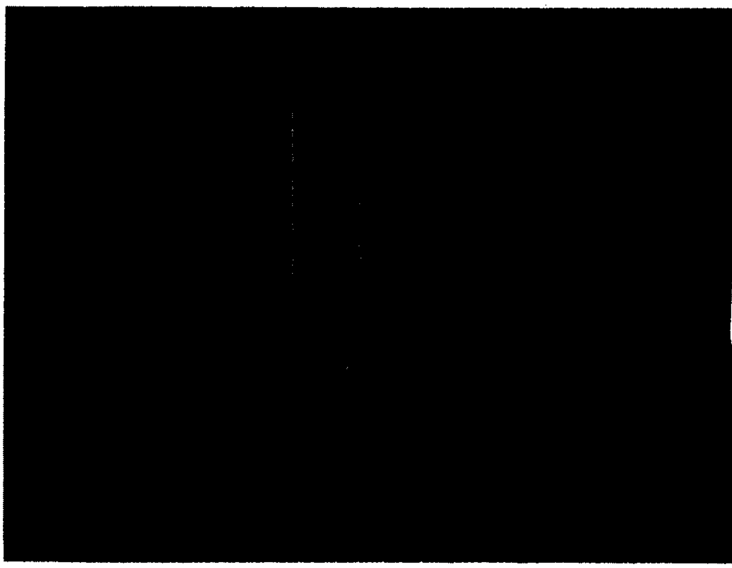
P5
∡ MKR FALLTIME
0.2 μSEC/CM



P5

VIDEO RISE TIME

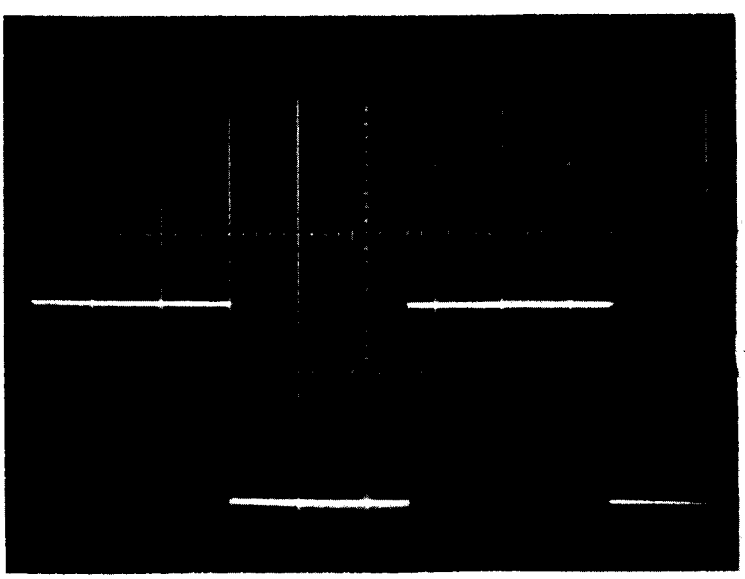
10 μSEC/CM



P5

VIDEO FALL TIME

1 μSEC/CM



$\bar{P}5$

REVERSE ∡ MKR. OUTPUT

2 V/CM

2 MSEC/CM

89.3 CPS FROM H.P. COUNTER